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ARTIFICIAL RESEEDING ON WESTERN MOUNTAIN RANGE LANDS

By

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and

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ARTIFICIAL RESEEDING ON WESTERN MOUNTAIN RANGE LANDS[1]

By C. L. FORSLING, *Director, Intermountain Forest and Range Experiment Station,* and WILLIAM A. DAYTON, *Plant Ecologist, In Charge of Range Forage Investigations, Forest Service*

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INTRODUCTION

Range lands in the western United States are subject, on the whole, to severe climatic conditions. The natural vegetation represents a survival of the fittest, particularly on the higher and the more arid ranges. Most of this range receives too scanty fall of rain or snow to support a complete ground cover. Through heavy use the carrying capacity of large portions of these range lands has been lowered, by destruction or lessening of the stand of the most palatable species and by the increase in the stand of inferior, worthless, and poisonous plants. The productivity has been further lessened in many cases by concomitant soil impoverishment and erosion and by

[1] The information contained in this circular is based largely upon results of experiments in artificial reseeding conducted on national-forest lands in the western United States since 1902. The most significant of these investigations up to 1912 are those reported by Griffiths, Cotton, and Sampson in the publications listed respectively as Nos. 10, 5, and 29 under Literature cited, p. 46. Sampson's work is now out of print, and numerous experiments have been conducted since 1912, particularly in central Utah by the Intermountain Forest and Range Experiment Station. The object of this circular is to take the place of the earlier bulletin by Sampson and in addition to present such later information as is applicable to mountain range lands or those of similar growth characteristics in the West. The material in the earlier publication has been drawn upon freely, without specific reference to all points included in this circular. Many members of the Forest Service have generously supplied information or otherwise aided in the preparation of this circular, and the writers gratefully acknowledge their indebtedness for this assistance.

the weakening of the forage plants and of their powers of reproduction. Some range lands naturally support a stand of vegetation of inferior value for grazing. These, if better forage species were introduced, would be materially increased in grazing capacity. The owners and users of range lands are continually seeking information on the practicability of artificial reseeding as a means of increasing the grazing capacity. To such queries no unqualified answer can be given. Success in reseeding depends primarily upon the climate and soil characteristics of the locality where it is tried out, as well as upon the species of plants used. On a large proportion of the western range land reseeding is entirely impracticable by any methods or plant species thus far tested, mainly because of the low rainfall. There are, however, more or less local areas of considerable acreage in the aggregate, characterized generally by moisture conditions above average and by ample length of growing season, where artificial reseeding adequately undertaken will justify the expense involved.

Serious erosion and washing away of the soil is occurring on much of the range land in the West as the result of thinning out of the plant cover by overgrazing or repeated fires, or both. Such depletion of the soil, if not arrested, will reduce the land to a barren waste. On areas where erosion has reached an advanced stage, even the exclusion of grazing may not result in sufficient revegetation to check erosion and restore the land to economical production within a reasonable time. Artificial reseeding offers considerable promise not only of arresting erosion but also of restoring the grazing capacity on these lands.

The purpose of this circular is to bring together the best available information regarding the conditions under which artificial range reseeding may be justified, the species that will give best results, and the methods that may be employed with the greatest success.

These suggestions will be of value chiefly in the improvement of land with superior growing conditions. Even on these lands, however, because of the wide range of conditions in different localities, and because of the many important points on which range investigations have thus far produced but scanty information, it is recommended that wherever artificial reseeding is contemplated in untried localities, the operator at first should undertake the work on a small scale or trial basis. The information in this circular will assist in the selection of the sites to plant, the species to use, and the practices to follow, and will at least make it possible to conduct the trials in a more intelligent manner.

Although the selection of suitable planting sites, the kinds of seed to sow, and methods to employ are of primary consideration, the cost of the seeding operations and of handling the land while the new crop is getting established must compare favorably with the value of the benefits to accrue, if the artificial reseeding of range lands is to be justified. A satisfactory stand of vegetation must be established at a cost that will be offset within a reasonable period by the resulting increased returns from the livestock. The average mountain range lands susceptible of artificial reseeding will rarely yield

a return that will justify an expenditure of more than $3.50 an acre for increasing the grazing capacity, and even the most economical seeding operations will frequently equal that amount. Only in exceptional cases with very favorable conditions is an outlay of as much as $5 or $6 an acre warranted. Just how far the landowner may go must be determined by local considerations. It is hoped, however, that the suggestions offered will assist him in determining what cost may be justified.

CONSIDERATIONS PRELIMINARY TO RESEEDING

CONDITIONS UNDER WHICH ARTIFICIAL RESEEDING IS PRACTICABLE

NATURAL REVEGETATION TO BE PREFERRED

The fact should be appreciated that in operations on any considerable scale, artificial reseeding of the range is not to be regarded as a substitute for methods of range management that will improve and maintain the crop of native forage plants through natural revegetation. Also where there is already a fair stand of palatable and nutritious native vegetation it will not pay to attempt plant introduction. Even where the native vegetation has been badly depleted but a few seed plants remain, it is usually more economical to increase the forage by so handling the range that it will improve naturally. The indigenous species ordinarily are better adapted to the growing conditions than are any of the plants available for introduction, and the protection and management that would have to be given to establish introduced species will equally well enable the native species to increase to the full productivity of the land. On areas where the range has reached such a bad stage of depletion that practically no palatable native plants remain to supply seed, the introduction of new plants by artificial seeding is the only practicable means of reclaiming the range. Only where the native forage is of inferior quality and not abundant enough to prevent establishment of introduced plants would much be gained if plants of higher forage value were artificially introduced.

CONTROL OF GRAZING IMPERATIVE

Even on areas where there is little or no hope for natural revegetation, artificial range reseeding should not be undertaken unless grazing can be restricted long enough to allow the introduced vegetation to become well established. Thereafter grazing should be regulated to a degree that will make it possible to maintain the stand. Disregard of this requirement may defeat the purpose of the work. It is best to keep livestock off during the first season and until late in the summer of the second year. During the first season the seedlings produce but little forage, and severe injury is likely to occur from trampling by the grazing animals. Some damage may occur if the area is grazed during the forepart of the second year, but by later summer or early fall the seedlings have usually attained a size and vigor that enable them to withstand light or moderate

grazing. Subsequent grazing should be comparatively light until a full stand has become established. Grazing should be kept light after the second year until the creeping plants have vigorous root-stocks or until the bunch-habit plants have stooled out well.

The idea is sometimes held that less care is needed with cultivated than with native pastures, once the stand is established. Under range conditions this view is not in accord with the facts. If artificial reseeding is undertaken in order to obtain a forage cover that will withstand heavier use than the native vegetation can survive, the operator may be disappointed. Of course, ability to resist grazing varies with species, but no forage plant can withstand indiscriminate use.

The requirements for handling range occupied by cultivated forage plants are practically identical with those for maintaining maximum economical forage production on native pasture lands. These requirements include such fundamental practices as (1) stocking the range within the limits of its carrying capacity; (2) delaying use of the range in the spring until the forage reaches a stage of development where grazing will not be injurious; and (3) the application of a system of use, such as deferred and rotation grazing, which will permit the plants to maintain their vigor and allow those which depend on seed for reproduction to mature and disseminate an occasional seed crop. Provision in the plan of range use for these important features of management will maintain the range at its highest productivity and at the same time insure full annual utilization of the forage crop.

Artificial reseeding may sometimes be employed as a supplemental measure in the management of range or other lands. In this event the costs may be figured on a more favorable basis than in an extensive range-improvement project. The seeding of cut-over timberlands as a measure of protection and to derive some revenue from them pending their restocking to timber, and the seeding of range to control poisonous plants are examples of the use of artificial reseeding as a supplementary measure.

SUPPLEMENTAL SEEDING

Clear cutting is practiced in logging operations in the Douglas fir region in the Northwest. Removal of the timber and burning of the slash may be followed by a heavy growth of weeds which are practically valueless for grazing and which create a considerable fire hazard until tree reproduction has progressed far enough to crowd them out. Seeding these cut-over areas to forage plants and using them for grazing until the time when the young trees crowd out the forage plants has been found practical as a means of reducing the fire hazard and gaining some supplemental income from the timberland. This method of use is advisable, of course, only where there is no danger of grazing interfering with reproduction of the timber and where growing conditions are satisfactory for early establishment of the forage plants.

Ingram (*13*)[2] has reported a number of successful seedings on logged and burned-off areas in the Cascades region of western Oregon. The seed, either orchard grass alone or in mixture with velvet grass and red and white clovers, was sown in the ashes in the fall or on snow late the following winter. Ingram found that if the seed is sown as soon as the ashes cool it germinates with the first fall rains and more mature root systems are thereby assured, provided there is sufficient snow in the winter to prevent frost heaving. Also, the plants themselves appear to be stimulated by the potash or other fertilizing elements of the ashes. On the other hand, sowing on the packed snow makes for a more even and sure seed distribution, since the swath can be plainly seen on the snow and logs are less difficult to surmount with a packed-snow cover. Good stands have been obtained with both methods. Teutsch reports a successful seeding by airplane in Coos County, Oreg., in the fall of 1927, of 1,000 acres of logged and burned-off land to orchard grass, perennial ryegrass, and white and alsike clovers. Forty-five pounds of seed per acre, costing about $1,000 altogether, was used, the seeding costs being $420, making a total cost of $1.42 per acre, an estimated net saving of $1,080 over the cost of hand seeding (*32*).

SUPPLEMENTARY SEEDING TO CONTROL POISONOUS PLANTS

In the control of poisonous plants, such as tall larkspur, by grubbing, the plant cover is thinned out more or less and the soil is left in fair condition to receive seed. Where native forage plants are not adequate to reseed the areas, the tendency is for worthless plants to come in and for the larkspur to become reestablished. Where growing conditions are favorable it is advisable to sow the seed of some native forage plants or the more promising cultivated species, since this insures earlier improvement of the range and tends to restrict reinfestation by obnoxious plants.

In a test conducted on the North Fork division of the Holy Cross National Forest, Colo., by Forest Ranger W. M. Scanlan and a stock permittee, Robert Reed, the seed of redtop[3] and orchard grass was sown in some small gulches, where monkshood (*Aconitum* sp.), larkspur (*Delphinium* sp.), and false-hellebore or skunkcabbage (*Veratrum californicum*) grew. No effort was made to thin out the native vegetation prior to seeding. Where the ground was sufficiently wet the redtop crowded out the weeds. On the drier areas, although a good stand of redtop was obtained, it was mixed with the false hellebore which the redtop seemed unable to displace.

COST AND RETURNS FROM ARTIFICIAL RESEEDING

In determining whether or not the expense involved in the reseeding process will be offset, within a reasonable period, by the resulting

[2] Italic numbers in parentheses refer to Literature Cited, p. 46.
[3] A check list of the common and scientific names of species mentioned in this circular appears on p. 45.

increased income from the range, the reckoning must include, in addition to the actual cash outlay for the seeding operations, interest charge on this outlay and other expenses chargeable to the project. The interest charges are influenced directly by the period required for a stand to become established. The return from the investment depends upon the permanency of the stand and the period over which it permits the whole financial venture to be spread, and also upon the increase in forage production. Where grazing use is a supplemental measure to reduce the carrying charge of timberland, pending restocking to timber, the timber-growing project and not grazing should carry the taxes and interest on the investment in land.

Other things being equal, the more inaccessible the area the higher are the costs of transportation and labor and the smaller the value of the land and its crop. High initial expense for seeding on areas difficult of access is therefore not often warranted. The principle involved in the realtor's maxim, "Don't put a $10,000 house on a $100 lot," applies here as elsewhere. The best growth conditions obtain on such range sites as mountain meadows, rich, loamy bottom lands, and the more fertile gentle slopes of moderate elevation and considerable extent, and there are the best possibilities for successful reseeding.

COST OF SEED PER ACRE

The initial cost of the seeding operation includes the items of seed and planting. The cost of the seed varies with the quantity required to obtain a satisfactory stand and the cost per pound. For example, the seed of Kentucky bluegrass costs at least about 24 cents a pound, and about 15 pounds to the acre are required to obtain a satisfactory stand. Hence, the cost is about $3.60 an acre for seed alone. Timothy seed, on the other hand, costs about 7 cents a pound, and at the rate of 8 pounds to the acre the cost is about 56 cents an acre. With the more expensive species, such as Kentucky bluegrass and white clover, especially when they also reproduce by rootstocks or stolons it is seldom, if ever, desirable under range conditions to use the full quantity of seed ordinarily recommended to obtain a full stand. These species may be sown in mixture with cheaper species or a half or a third of the full quantity may be used and the new growth protected and given time to spread naturally. Such reductions in seed must be determined upon the basis of prevailing circumstances in each case. The minimum quantities of seed to use for obtaining a satisfactory stand of a number of cultivated species on western range soils of high productivity, as well as the approximate cost of seed per pound and the approximate cost per acre, are included in Table 1.

TABLE 1.—*Best species for reseeding ordinarily good sites on western mountain range land, with cost of seed* [1]

SITE 1.—NEAR TIMBER LINE ON INLAND MOUNTAIN RANGE LANDS

[Average annual precipitation, 30+ inches; growing season 75–90 days]

Species [2]	Propagates naturally by—	Seed per acre	Cost of seed per pound	Cost of seed per acre
		Pounds	*Cents*	*Dollars*
Seed available on market:				
Common bromegrass	Rootstocks	15	0.15	2.25
Kentucky bluegrass	do	15	.24	3.60
Canada bluegrass	do	15	.21	3.15
Redtop [3]	do	8	.17	1.36
Seed not available:				
Violet wheatgrass [4]	Seed	15		
Big mountain bromegrasses [4]	do	20		
Thickspike wheatgrass [4]	Rootstocks and see	15		

SITE 2.—MEDIUM TO HIGH ELEVATIONS, BELOW TIMBER LINE, OF INLAND MOUNTAIN RANGE LANDS

[Average annual precipitation, 25+ inches; growing season 100+ days]

Seed available on market:				
Common bromegrass	Seed and rootstocks	15	0.15	2.25
Kentucky bluegrass	do	15	.24	3.60
Canada bluegrass	do	15	.21	3.15
Timothy	Seed	8	.07	.56
Orchard grass	do	12	.21	2.52
Slender wheatgrass [4]	do	15	[5].13	[5]1.95
Redtop [3]	Seed and rootstocks	8	.17	1.36
Red clover	Seed	10	.33	3.30
White clover [6]	Seed and stolons	6	.36	2.16
Alsike clover	Seed	6	.30	1.80
Italian ryegrass	do	15	.14	2.10
Sheep fescue	do	12	[5].32	[5]3.84
Tall or meadow fescue	do	12	[5].16	[5]1.92
Bur clover [7]	do	10	[5].15	[5]1.50
Seed not available:				
Big mountain bromegrasses [4]	do	20		
Violet wheatgrass [4]	do	15		
Thickspike wheatgrass [4]	Seed and rootstocks	15		
Quack grass	do			

[1] The seed prices given in this table are based on average 1928 quotations on good-grade seed from representative western seed houses for 100-pound lots and are exclusive of freight or other transportation charges. Wholesale prices such as could be procured by cooperative buying on competitive bid should be materially lower than those shown in the table. It is understood, of course, that the market price of seed is fluctuating more or less continually. Prices for 1928 have been compared with similar averages for 1931. In general there is no very great difference, some species commanding somewhat higher prices in 1931, while others are a little lower. 1928 prices are preferred as possibly representing more nearly normal conditions throughout the West. Prospective purchasers for range reseeding should watch the market and take advantage of the lower quotations. Growing season as used in this table refers to the period from the average date when the more common herbaceous plants begin growth in the spring until average date when growth ordinarily ceases on account of lowering temperatures in the fall. This is somewhat longer than the normal "frostless season," since most of the forage plants withstand some freezing temperatures without serious consequences in both early spring and late fall.

[2] With the exception of those listed under the head "Seed not available," probably all species but one occur on western ranges exclusively as introductions.

[3] In wet meadows only.

[4] Native species.

[5] Prices based on 1931 averages, in the absence of 1928 figures.

[6] In moist meadows only.

[7] On warm moist sites.

TABLE 1.—*Best species for reseeding ordinarily good sites on western mountain range land, with cost of seed*—Continued

SITE 3.—LOWER MOUNTAIN SLOPES AND HIGHER FOOTHILLS OF INLAND MOUNTAIN RANGE LANDS

[Average annual precipitation, 17 to 25 inches; growing season 120+days]

Species	Propagates naturally by—	Seed per acre	Cost of seed per pound	Cost of seed per acre
		Pounds	*Cents*	*Dollars*
Seed available on market:				
Common bromegrass	Rootstocks and seed	15	0.15	2.25
Crested wheatgrass	Seed	15	[5].18	[5] 2.70
Slender wheatgrass [4]	do	15	[5].13	[5] 1.95
Yellow sweetclover [8]	do	10	.10	1.00
White sweetclover	do	10	.11	1.10
Alfalfa [9]	do	10	[5].22	[5] 2.20
Seed not available:				
Blue-bunch wheatgrass	do	15		
Bearded wheatgrass	do	15		
Bluestem	Seed and rootstocks	15		
Thickspike wheatgrass	do	15		
Streambank wheatgrass	do	15		
Violet wheatgrass [10]	Seed	15		
Big mountain bromegrasses [10]	do	20		

SITE 4.—MOUNTAIN RANGE ON WEST COASTAL SLOPE

[Average annual precipitation, 40+ inches; growing season 120+ days]

Seed available on market:				
Orchard grass	Seed	12	0.21	2.52
Timothy	do	8	.07	.56
Redtop	Seed and rootstocks	8	.17	1.36
Italian ryegrass	Seed	15	.14	2.10
Tall or meadow fescue	do	12	[5].16	[5] 1.92
Bulbous bluegrass	do	(11)	.75	(11)
White clover	Seed and stolons	6	.36	2.16
Smilo grass	Seed			

SITE 5.—FOOTHILL RANGE LANDS OF THE SOUTHWEST

Alfileria	Seed	(11)	[5] 0.90	(11)
Australian saltbush	do	(11)	[5].75	(11)

[4] Native species.
[5] Prices based on 1931 averages, in the absence of 1928 figures.
[8] Biennial, growing conditions must permit production of viable seed.
[9] Well-prepared ground only.
[10] On moister sites only.
[11] At the 1931 price indicated, use of this species under range conditions is at present prohibitive, except where it is sown purely for the purpose of introducing the species and looking to later reproduction to thicken the stand.

COST OF OTHER ITEMS

The items of cost other than seed include transportation, scattering the seed, and soil treatment. Cost of transportation varies with different methods that may be used, distance, cost of labor, and cost of use of equipment. It is cheapest where a short haul over a good wagon road is possible and greatest where it is necessary to convey seed long distances on pack animals. Except in extreme cases the cost of transportation ordinarily will not exceed 40 or 50 cents to the acre and usually is much less. An experienced man can sow not less than 10 acres each day with a hand seeder or broadcast by hand, provided the land to be sown is not cut up into small isolated tracts or is not difficult to get over. Under these favorable conditions,

with wages figured at $4 a day, sowing will amount to about 40 cents per acre.

The cost of covering the seed after sowing varies with the methods used. Plowing followed by harrowing may run up as high as $3.50 or $4 per acre. Going over the area once with a steel-tooth harrow will cost about 50 cents an acre for each treatment, and a single treatment with a brush drag or an A wooden-peg harrow will cost about the same. Trampling the seed in with sheep costs practically nothing if the sheep are already in the vicinity of the area to be planted. Cost will largely decide the method to be used, but the effectiveness of the method must also be considered.

TIME REQUIRED FOR A STAND TO BECOME ESTABLISHED

Few species reach maximum production in less than two years, and others require as many as five years under favorable conditions. Species that get well started by the second year include many of the bunch grasses such as timothy, orchard grass, and mountain bromegrasses. Some of the plants with rootstocks are slower in reaching a point where the forage yield is high. Kentucky bluegrass is especially slow, often requiring five years or more. The more adverse the growing conditions the longer will be the time for any of the species to get well under way. Short, cool growing seasons and scanty moisture or periods of drought operate to slow up the development of the vegetation. From the time of sowing to the establishment of the stand the initial cost of seeding is augmented by the accumulation of interest on the initial cost and on the value of the investment in land and by taxes.

PERMANENCE OF THE STAND

To be economically justified, artificial reseeding must result in a forage crop so "permanent" that the seeding operations will not have to be repeated before the cost of the original planting, plus accrued interest and any other costs, has been retired. Success in this respect will depend upon whether species used are long-lived, upon their ability to reproduce promptly under reasonable protection, and upon the manner in which the forage is utilized. Most of the perennial bunch grasses live 8 to 10 years or longer on the favorable sites, but some are inclined to run out in about 5 to 7 years on less favorable sites. The plants with running rootstocks are not likely to die out for a great many years, except in cases where the stand is so dense that it becomes sod bound, which seldom occurs on range land. Some of these plants will die because of adverse climate and from other causes, but if the vegetation is able to propagate from seed or any vegetative means the stand will normally be renewed and improved. The length of life of the forage plants and their ability to revegetate both depend upon management that will prevent overgrazing and insure production of seed. Careful selection of species and judicious management may reasonably be expected to result in the stand of introduced species becoming permanent.

THE VALUE OF THE INCREASE IN FORAGE PRODUCTION

Where a stand of highly palatable grass occupies 60 per cent of the ground surface and is attaining good height growth and foliage development, the reseeded range should carry livestock at the rate of 3 or 4 acres for a grown cow or three-fourths to 1 acre for a grown sheep for a grazing season of three months. Where good pasturage is worth as much as $1 per head per month for cattle and $0.25 per head per month for sheep,[4] the forage on the more productive range lands thus seeded would yield an annual return of $0.75 to $1 for each acre. Obviously, however, forage production will vary with growing conditions and will be lower on thin, rocky soils or where climatic conditions are not the most favorable. Furthermore, the value of the forage will depend upon the market price of livestock in each locality and the use to which the forage is put.

EXAMPLES OF PROFITABLE RESEEDING

With so many factors contributing to the determination of whether or not artificial reseeding is profitable, it is impossible to state offhand the exact localities where reseeding will or will not pay. This can be done only after careful analysis of the conditions obtaining in each case. The following three examples are indicative of the time required to liquidate reseeding costs under diverse but typical western range conditions.

In each of the following examples no charge is included for taxes or interest on the investment in land, since the areas were on Federal land not subject to these costs. These items may often be left out in computing the costs on privately owned range. On range lands are many small areas, depleted from some cause or other, that are not being reseeded naturally from the native vegetation on adjoining range. The owner already has his money invested in this land, and no distinction is made in taxing the depleted areas as compared with areas in good condition. Often such depleted areas are the choicest parts of the range and may be expected to respond well to artificial reseeding. In such cases the owner is justified in going to a greater expense for seeding than where it is necessary to figure taxes and interest on the investment in land as part of the cost of the operation.

A badly denuded area on sheep range in the Wasatch Mountains of central Utah was sown to Kentucky bluegrass in the fall of 1914. Practically all the native palatable plants had been destroyed by heavy overgrazing prior to that time, and the carrying capacity had been reduced to a point where it was not profitable to graze sheep. The planting was done for $4.50 an acre, which included seed, transportation, sowing, and harrowing the ground. By 1917, the third year after planting, a stand vigorous enough to be grazed had become established. The yield of forage sufficed to carry sheep at the rate of 3⅓ acres per head for the 90-day grazing season. By 1920, the stand had increased sufficiently to support a sheep on each 2 acres for the season, and at the end of nine years 1 acre was sufficient to support a sheep for the 3-month grazing period. Here the value of

[4] These are approximate average maximum commercial figures. Pasturage on national forest land is admittedly at a rate considerably below a commercial basis.

sheep grazing was figured at $0.75 a head for the season, and interest on the cost of seeding at the rate of 6 per cent compounded annually. The interest charged exceeded returns for grazing until the tenth year after the seeding was done. Following that year, however, the value of the grazing was adequate to pay a fair income and, in the eighteenth year after sowing, the investment will be retired and dividends thereon will be realized. Kentucky bluegrass is a highly persistent and long-lived plant. It is able to spread by rootstocks and, if properly managed, maintains itself indefinitely.

In another example, where common bromegrass was used, it required eight years for the original cost and the accrued interest to be retired. The total cost of seeding in this instance was $3.28 an acre. The carrying capacity under full production, which began in the third year after reseeding, was 1 acre for a sheep for a 90-day season. Grazing was valued at $0.75 a head for the season, and interest was computed at the rate of 6 per cent on the initial cost of seeding. Common bromegrass is a long-lived plant that spreads by rootstocks and should not require reseeding for many years.

The third example deals with an area sown to timothy in a region where this species will grow well. The original cost of seeding amounted to $1.34 an acre. Grazing is valued at $0.75 a sheep for the 90-day season. The area was fully producing the third year after seeding, the carrying capacity being 1.2 acres for each sheep. In this instance, because of the relatively low original cost, the return from the increase in forage supply exceeded the interest charge in the third year after sowing, and the original cost was retired in a little more than four years. After about eight years, as frequently happens with timothy, the stand began to thin out, although after 16 years many plants were still in evidence.

SITE CONDITIONS SUITABLE FOR RESEEDING

Whether introduced plants will grow depends upon the suitability of growing conditions on the range, including moisture, length of growing season, character of the soil, and the extent of the native vegetation with which the seeded plants will have to compete. These points are discussed in detail in the following pages.

MOISTURE REQUIREMENTS

Moisture is the most important single factor to consider in artificial reseeding of practically all western mountain range lands. (Fig. 1.) The chief exceptions are in the Cascades of Washington, on the western slope of the Cascades of Oregon, and in the Sierra Nevada and coast ranges of California, where the rainfall is heavy enough to allow sufficient moisture for growth of introduced species, even when much of the precipitation is lost in run-off and evaporation. Species differ somewhat in moisture requirements, but none have been found that give satisfactory results where the annual precipitation is less than approximately 17 inches, of which not less than about 6 inches falls during the main growing season. When special effort is made to prepare the soil for conservation of moisture, fairly satisfactory results have been obtained with certain dryland forage crops in the Southwest with 15 inches of rainfall and

farther north with even a smaller amount. It is impractical, because of cost, to give such soil treatment on range lands, although such measures should be taken advantage of in seeding abandoned dry farm lands to range plants.

Even with 17 inches of precipitation, properly distributed, only the more favorable sites where the soil remains fairly moist most of the growing season should be chosen. Such localities include mountain meadows that are irrigated by run-off from surrounding terri-

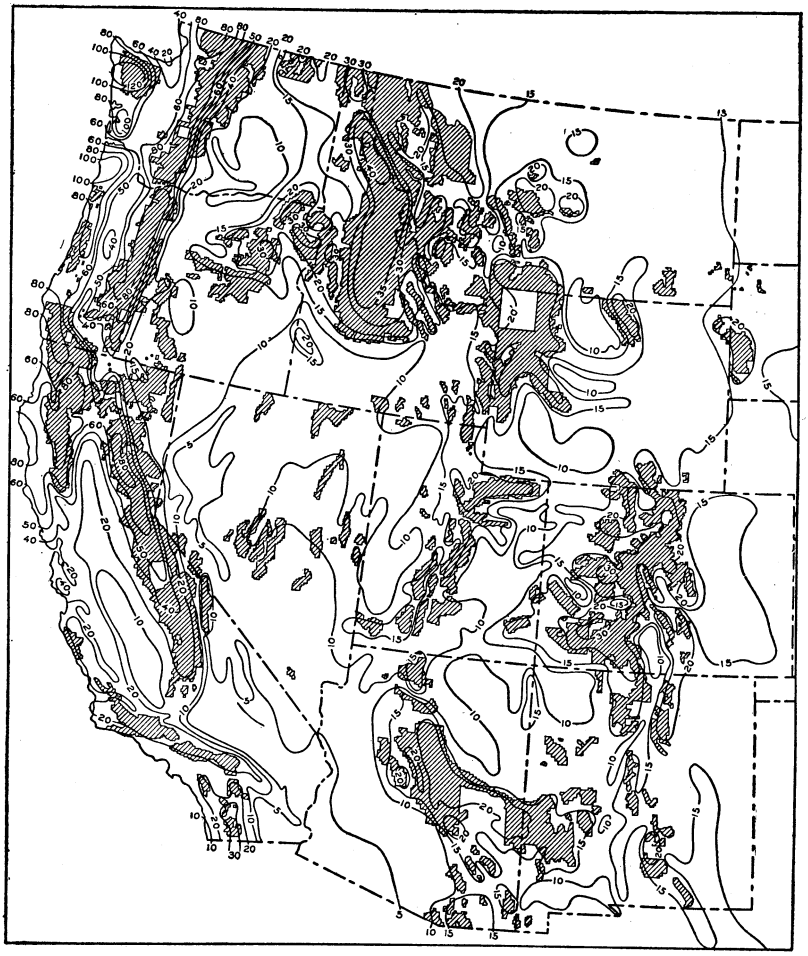


FIGURE 1.—Approximate precipitation in the western part of the United States. (Hatched areas represent national forests)

tory, fairly level parks protected against high winds and excessive evaporation, moderate north slopes having a fairly deep, fine-textured soil, and any other sites that do not dry out readily. Areas to be avoided are steep slopes; slopes exposed much of the day to the sun or to the prevailing wind; areas of coarse, loose, or shallow soils or soils low in organic matter; and sites where other conditions are unfavorable for the retention of moisture in the soil.

Rainfall in almost any locality in the West varies materially from year to year. If sowings are attempted in a year of deficient moisture, failure may be expected. Plantings made during a wet year and especially at the beginning of a series of wet years should yield excellent results. Forage plants that have become well established will ordinarily survive the dry periods.

LENGTH OF GROWING SEASON

Altitude affects the length of the growing season, and this materially influences the success of many species. As altitude increases the growing season becomes shorter. When the growing season is less than 100 days only the strongest and best seedlings become established, and even this scanty stand may be thinned out materially the first season. Plants which get started at excessive elevations are likely not to make vigorous growth, and rate of spread is interfered with. Artificial reseeding with timothy, Kentucky bluegrass, and redtop at 4,800-foot and 7,800-foot elevations in the Blue Mountains of northeastern Oregon resulted in average deficiencies at the higher elevation of (1) over 50 per cent in the height growth; (2) nearly 60 per cent in vegetative density; (2) over 76 per cent in estimated annual yield; and (4) approximately 85 per cent in viability of seed crop. In general those areas at altitudes sufficient to have satisfactory rainfall and yet not too near timber line give best results.

The elevations above which other than native species may be used successfully vary with individual species. None of the cultivated plants have yielded good results when tried out above timber line. Species which depend mainly upon seed for reproduction, such as timothy, orchard grass, and many of the clovers, can seldom develop sufficiently to produce fertile seed when grown within 1,000 to 1,500 feet of timber line. Unless viable seed is produced, such species are unable to maintain and improve the stand. Other species, such as common bromegrass and Kentucky and Canada bluegrass, which propagate from rootstocks and are not dependent upon seed for regeneration, can be grown at slightly higher elevations in the same region, but none of them yield very well above timber line.

SOIL

The soil should be fairly deep, with considerable organic matter; it should not be too coarse, should be free from acidity (unless acid-resisting species are used), and should be in fair tilth. Fine texture is of great importance, because of its effect on moisture. Coarse soils, which readily lose their water content through percolation and evaporation, should be avoided. Depth also is of importance in retaining moisture; shallow soils dry out much more readily than the deeper ones.

Soil acidity and lack of oxygen may enter in on poorly drained places where the ground is saturated the greater part of the season. In such localities the soil may be acid or sour in varying degrees, owing to the accumulations of organic matter. Species adapted to such sites must be used if success is to be attained.

EFFECT OF NATIVE VEGETATION

Ordinarily it is much simpler to establish and perpetuate a satisfactory stand of introduced species where the hardy native species have been largely destroyed, provided that the soil has not been depleted through erosion. Soil preparation in such places is a minor matter, and there is little or no competition of the introduced species with native vegetation. Where the perennial native vegetation, particularly persistent perennials such as shrubs or rank-growing weeds, occupies 60 per cent or more of the ground, the site may be producing the maximum amount of vegetation that it is capable of supporting, and the introduced species may not be able to compete successfully for moisture and light with the more hardy natives. Plowing prior to reseeding will eliminate the native vegetation but, because of the cost involved, such intensive cultivation is not warranted except where reasonably high returns may be expected.

Burning is frequently suggested as a means of destroying rank, worthless shrubs such as sagebrush and is reported to have been tried successfully in some localities. It may prove practicable for clearing range land where conditions are such that damage will not be done to the soil, forage, or other land resources. However, the safe methods to employ in burning are so little understood that it should only be tried with great caution and experimentally. Brush cover has a value in preventing erosion on sloping lands, and if a new cover is slow in becoming established after burning, the soil may meanwhile become materially damaged and the streams badly silted.

SELECTION OF SPECIES

Of first importance in the choice of species for artificial range reseeding is the selection of plants adapted to local conditions. Of almost equal importance is the probable cost of the seeding operations as measured in terms of possible returns. Seed is the principal item of expense, and, therefore, the species used must be resistant to grazing and trampling and be able, under reasonable grazing use, to produce a volume of palatable and nutritious forage sufficient to repay the cost of the seeding operations. Since full productivity can seldom be attained in one year, it is very important that the species be able to reproduce and improve or maintain the stand under given soil, climatic, and grazing conditions.

The ability of plants to become established, resist grazing, and improve and maintain the stand under adverse conditions depends largely upon the method of reproduction. In this respect forage plants, and especially grasses, fall into two groups, namely, those which depend mainly upon seed for regeneration, and "creeping" plants or those which, in addition to producing seed, reproduce vegetatively, by rootstocks or stolons. (Table 1.)

Stolons are trailing or reclining stems above the ground which strike root where they touch the soil and then send up a shoot which has roots of its own and becomes an independent plant when the connecting part dies. Rootstocks (botanically known as rhi-

zomes) are in reality stems which creep along beneath the surface of the ground and send forth shoots which eventually become individual plants when the portion connecting them with the parent plant dies. Such plants are independent of seed production for spreading and establishing a turf and are generally able to withstand grazing and trampling well.

Curly mesquite grass (*Hilaria belangeri*) of the Southwest is one of the most common native grasses which reproduce by stolons. White clover (*Trifolium repens*) is a common cultivated forage plant with stolons. Of the common grasses that spread by rootstocks, cultivated Kentucky bluegrass and common bromegrass and the native bluestem wheatgrass (*Agropyron smithii*) are probably the most familiar examples. Bermuda grass (*Capriola dactylon*) has both rootstocks and stolons.

Those plants which are wholly or almost wholly dependent upon seed for regeneration, such as timothy, orchard grass, and the common native bunch grasses, must be grown and grazed under conditions that will permit the production of seed, conditions often lacking at the higher elevations. Furthermore, having no creeping underground rootstocks, these plants are less resistant to overgrazing and trampling than plants with rootstocks. Most bunch grasses have the ability to thicken the stand by tillering (sending up new shoots from the original crown) and enlarging the size of each individual bunch or tuft. Under favorable conditions they will occasionally form almost a complete ground cover. The common blue grama (*Bouteloua gracilis*) of the western plains is one of the best examples of those grasses lacking true creeping rootstocks that in favorable localities will produce almost a complete cover.

The superiority as turf formers of plants which possess creeping rootstocks makes it desirable to give them the preference wherever growing conditions and cost of seeding will permit. On the other hand, when conditions are favorable for maturing an abundant seed supply, the "bunch-habit" plants are particularly desirable. In view of the variation among species it is necessary to consider each separately, in order to select the species best adapted to the locality to be sown.

The species best adapted to each of the rather broad site classifications of the mountain range lands of the West are summarized in Table 1. In each group the species are listed in the order of their general adaptability for range use. More detailed information for each species is given in the following pages, where brief discussions are also given of a number of little-tried species, many of which have shown promise for artificial reseeding and should be tried out further wherever opportunity affords.

CULTIVATED AND INTRODUCED CREEPING GRASSES

Introduced and cultivated creeping grasses which have proved fairly satisfactory under the more favorable growing conditions on western mountain grazing lands include common bromegrass, Kentucky bluegrass, Canada bluegrass, redtop, and quack grass.

COMMON BROMEGRASS

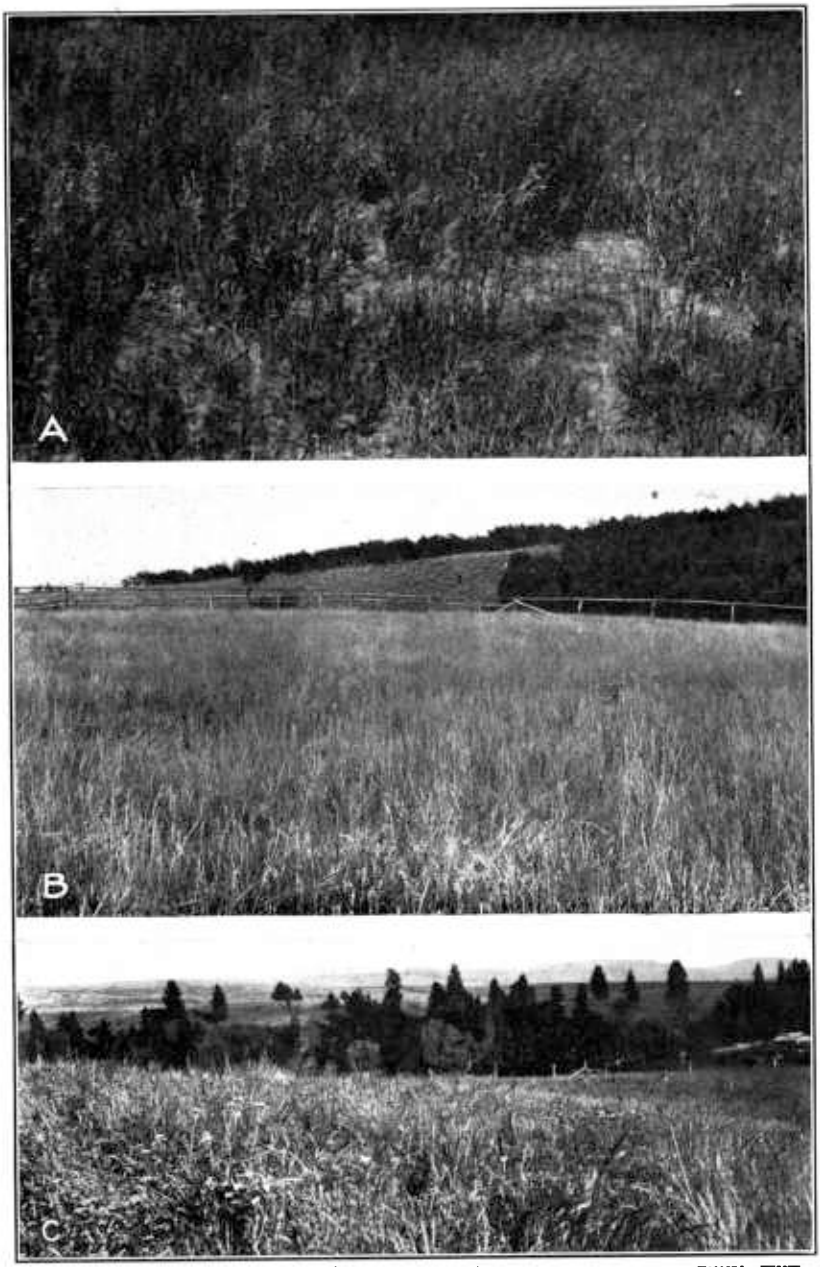
Common bromegrass (*Bromus inermis*), known also as smooth brome, awnless brome, field brome, Hungarian brome, and common brome, is a long-lived perennial and one of the most successful of the cultivated species introduced in the mountains of the West. It does well from the foothills to above timber line. In Alaska it is regarded as the most satisfactory grass for hay and pasture thus far introduced (*8*). It produces a good stand on soils that are fairly moist and not too shallow or rocky, and it resists drought well. The strong, well-developed rootstocks enable the plant to reproduce satisfactorily at high elevations and also to withstand trampling and grazing. It is a heavy seed producer, except near timber line. Under the more favorable conditions obtaining on mountain ranges this grass produces a rank stand 2 or 3 feet in height, but on poor sites the growth may be thin and not more than 10 to 12 inches high. The carrying capacity accordingly varies with soil and moisture. Yields as high as 3¾ tons per acre have been reported on the best soils and under the best growth conditions, but on ordinary mountain range the average yield is hardly half that amount. Although according to chemical analyses common bromegrass is not quite so nutritious as some other grasses, livestock do remarkably well on it. Its marked drought resistance gives it a wide sphere of utility. (Pl. 1, A.)

Common bromegrass spreads fairly rapidly in good soil, and the stand normally thickens in a few years. Under the best conditions for germination and seedling growth a full stand will be attained the second year. This, however, requires sowing at the rate of about 25 pounds of seed to the acre, and under western range conditions it is frequently more practical to sow about 15 pounds to the acre and graze only lightly the first few years. The use of common bromegrass as a hay and cultivated pasture grass, especially under dry farming, has been outlined in another publication (*25*).

KENTUCKY BLUEGRASS

Kentucky bluegrass (*Poa pratensis*) has given good results in establishing a stand of excellent forage on mountain grazing lands, where the annual precipitation averaged well over 15 inches, especially on limestone soils. (Pl. 1, B.) It is an excellent forage for all classes of livestock, produces an abundance of leafage, and, if moisture is ample and air temperatures do not rise above 90° F., remains green, palatable, and nutritious throughout the summer. Its chief drawbacks are the long time it takes for the establishment of a satisfactory stand and the high cost of the seed.

This species grows well in the moister regions of the West where the soil is not water-logged. It is commonly, though locally and usually rather scatteringly, established on western mountain grazing lands, either through accident or design, and it is not impossible that certain varieties or forms of the species may even be native in some localities. Kentucky bluegrass occurs sparingly in unusually favorable sites of the Southwest, but experimental reseeding tests with this species in that region have been unsuccessful; the seedlings gen-



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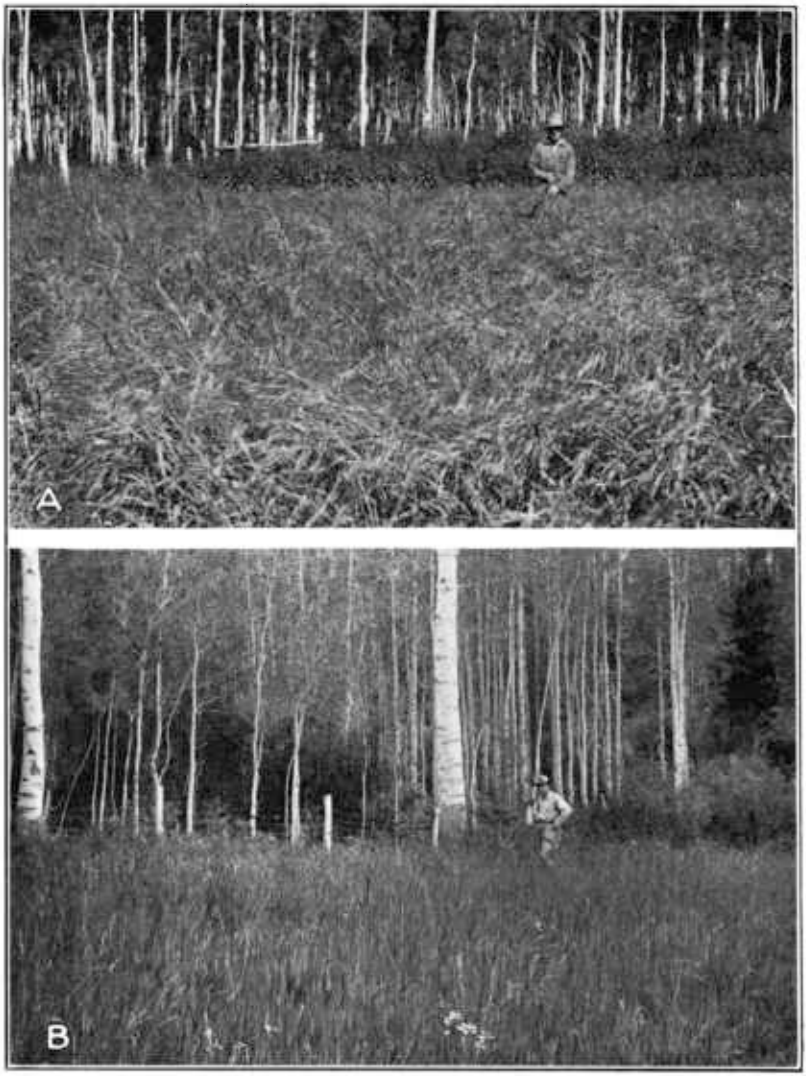
A, Common bromegrass artificially reseeded in a dry meadow of the Wasatch Mountains, Utah, at 9,600 elevation. The cover in the foreground, although annually grazed, is dense and the growth is vigorous; B, a stand of Kentucky bluegrass established by artificial reseeding in Hayden National Forest, Wyo. Area seeded and then tramped by sheep; C, an Oregon mountain pasture sown to timothy



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A, Large mountain bromegrass, artificially reseeded on the Wasatch Plateau, Utah, at an elevation of 8,850 feet; B, violet wheatgrass with some volunteer large mountain brome sown at an elevation of 8,850 feet in Utah. This native species is well adapted to artificial reseeding

erally die during the late fall and spring as a result of frost heaving and drought.

Indications are that Kentucky bluegrass seed germinates better with light, and the seed should barely be covered after sowing.

CANADA BLUEGRASS

Canada bluegrass (*Poa compressa*) is a hardy perennial, resembling Kentucky bluegrass in appearance, forage value, and growth habit. It is a somewhat smaller species, however, the leaves usually being a little shorter, and it is considered slightly less productive. It grows in a great variety of soils, becomes established on somewhat poorer, drier soils than Kentucky bluegrass will well endure, and is very persistent when it becomes established. Under range conditions 15 pounds of seed an acre is commonly used. Although the species has not been tried out in an experimental way on western ranges so extensively as have some other species, results in that region, as elsewhere, indicate that Canada bluegrass has considerable value for range reseeding. Information concerning Canada bluegrass as a cultivated pasture and lawn grass may be found elsewhere (*24*).

REDTOP

Redtop (*Agrostis palustris*)[5] is variable in size and accommodates itself to a great variety of sites. It is essentially, however, a plant of moist to wet meadows. Under such conditions, particularly on wet acid sites, it does better than any other cultivated grass, but on drier sites other grasses usually give better results. On suitably moist soils, which are conducive to rapid growth and early establishment, it is usually desirable to sow sufficient seed to obtain a full stand (about 8 or 10 pounds to the acre). Redtop seed, as purchased in the market, fortunately has greater relative purity than that of many other species. Its diminutive size, however, precludes any but very shallow soil treatment. The use of this species for cultivated pastures is described elsewhere (*2*, *24*).

QUACK GRASS

Quack grass (*Agropyron repens*), sometimes called couch grass, is a species of wheatgrass, propagating by rootstocks as well as from seed. Because of its aggressive habits of growth and the difficulty of eradicating it, quack grass is considered a pest on farm lands (*14*). In the western range country, however, these characteristics, combined with a fair forage value, highly commend it. Probably because of its eastern ill repute and classification as a weed, quack grass has not been given much recognition as a range forage plant nor much opportunity to prove its qualifications for this purpose. Where tried, it has given results sufficiently satisfactory to warrant additional experiment.

Quack grass starts growth early and requires a fairly good, moist soil. It is not killed out by severe winters or cool summers, and has

[5] Often referred to in literature as *Agrostis alba*. The name used above is preferred by the U. S. Department of Agriculture.

notable ability to withstand spells of hot, dry weather. Chemical analyses of the herbage indicate a high nutritive value. Care must be exercised with its use that there may be no danger of its spreading into agricultural land, where it might soon prove a pest. For this reason it may best be used at the higher elevations where seed will not mature. The chief disadvantage of quack grass under the more favorable growing conditions is its overdevelopment of rootstocks. The plant tends to become root bound about the third or fourth year after sowing, and plowing, harrowing, or disking is required to correct this condition. However, these conditions are not encountered frequently on the range. Quack grass is best sown in mixture with other grasses, such as orchard grass, meadow fescue, and perennial ryegrass.

CULTIVATED AND INTRODUCED BUNCH GRASSES

The cultivated grasses dependent mainly on seed for reproduction which have given fair results under certain western range conditions include timothy, orchard grass, Italian ryegrass, tall (or meadow) fescue, and sheep fescue.

TIMOTHY

Timothy (*Phleum pratense*), by far the most important hay grass cultivated in North America and the one so common in farm meadows and pastures of the northeastern quarter of the United States, has given better all-round results than any other species when tried out on western range sites where the soil is moist and the growing season is of sufficient length for seed production. Also, the seed is cheap as compared with that of most other species of cultivated forage plants.

Timothy becomes established by the second year after seeding and because of its tall stature, large leaves, and luxuriant growth produces a great abundance of nutritious herbage which is highly palatable to all classes of livestock. It holds up very well if properly grazed but does not endure overgrazing so well as most of the species with creeping rootstocks. Timothy will grow under a wide diversity of site conditions but thrives best in well-drained but moist loams or clays, at 3,000 to 5,000 feet elevation. (Pl. 1, C.) It is used extensively on moist areas in the Pacific Northwest.

On good range soils timothy has held up as long as 12 years or more, but ordinarily the stand tends to die out in about 6 or 7 years. In localities where fertile seed is produced the seed is often carried by livestock, wind, and other agencies to adjoining areas. Though near timber line where the growing season is too short to allow viable seed to mature, the species does not revegetate when killed out, the low cost of the seed justifies its use on sites where it may become established readily. It is of considerable value for use with a slow-starting perennial such as Kentucky bluegrass.

Eight to fifteen pounds of seed per acre is required to produce a good stand. It seldom, if ever, pays to sow less than 8 pounds per acre on the range, since seed can usually be obtained for 5 to 15 cents a pound and a good stand becomes established promptly.

Information relative to timothy as a cultivated hay and pasture grass is given elsewhere (*6*, *24*).

ORCHARD GRASS

Orchard grass (*Dactylis glomerata*) produces an excellent stand of tender green forage when sown in a fairly moist soil but does not do so well where summers are cool and short. It is best adapted to sites where there is an ample supply of moisture, and it thrives in limestone soils. Orchard grass is better adapted to grow in the shade than most of the cultivated species and consequently can be used to advantage under timber which is not too dense. Under favorable conditions it forms tufts 6 to 8 inches in diameter. It withstands fairly close grazing and is slow to die out when once established. On favorable sites it does best in thick stands, since the herbage then does not get woody. Fifteen to twenty pounds of seed per acre is generally required to produce such a stand. Twelve pounds per acre is recommended for range purposes when there is little danger of the plants becoming woody.

Orchard grass has been satisfactorily employed in reseeding logged-over lands in western Oregon (*13*). The slash is burned in the fall and the seed sown on the ashes then or on snow late the following winter. Sowing on packed snow is easier and makes for more even and sure distribution. Good stands have been obtained with both methods. Late spring seeding has invariably given poor results. When 15 pounds of seed per acre was sown in 1920, the costs varied between $2.16 and $3.08 per acre. The carrying capacity becomes about 10 to 12 surface acres per cow for the 7-month grazing season. Rentals per head for unfenced reseeded lands in this locality vary from about $1.50 for a short season to $2.50 for practically a year-long term.

Orchard grass as a pasture and hay plant is discussed elsewhere (*24*).

ITALIAN RYEGRASS

The effective range of this species (*Lolium multiflorum*) is limited to localities where the climate is warm and moist, such as the Pacific coast. Although, under farming conditions, Italian ryegrass is regarded as an annual, it is really a biennial or triennial grass and has to be started from seed the second, third, or fourth year. This, of course, eliminates it from serious consideration for seeding at high elevations or where drought would affect seed production. However, it produces a good stand of excellent forage early after sowing and consequently is of considerable value when mixed with a slow-starting perennial such as Kentucky bluegrass. When sown in mixture with other grasses or clovers about 8 to 10 pounds of Italian ryegrass seed per acre is recommended (*3*). Perennial ryegrass (*Lolium perenne*) probably has possibilities in the better range lands of moderate temperatures but trials with it have thus far been too limited to warrant any definite recommendation.

TALL, OR MEADOW, FESCUE

Although this species (*Festuca elatior*)[6] has not been tried out extensively under western range conditions it has given some fairly

[6] *Festuca pratensis*, the meadow fescue of the seedsman, is a synonym; it is smaller than typical forms of *F. elatior*.

good results where tested. In the Cascades of Washington (*5*), in 1903–1904, tall fescue made a good stand and excellent growth. It does best where moisture is plentiful, it has few equals in wet situations, and its altitudinal limit is rather high. It is typically a large species, is remarkably long-lived, and produces an abundant crop of fairly palatable foliage which starts growth as soon as snow is gone and remains tender and palatable late in the year. The plant is notably frost resistant. It does not, however, make a complete ground cover, and for this reason is to be recommended for sowing in mixture rather than alone. Though slower than timothy in getting established, it is more persistent than that species.

Information regarding meadow fescue for cultivated pastures and meadows is given elsewhere (*24*, *35*).

SHEEP FESCUE

Sheep fescue (*Festuca ovina*), the cultivated form of which is probably of the same species as common forms of fescue in the Rocky Mountains and elsewhere in the West, is reported as having given satisfactory results in Canada, but results with it in the western part of the United States have not been so promising. Some trials in the Northwest in 1903 (*5*), in which a fair stand was obtained from seeding, indicate that it does not hold up well. In cultivated pastures, where the soil is poor, sandy, or gravelly, sheep fescue does better than most grasses (*24*).

CRESTED WHEATGRASS

Crested wheatgrass (*Agropyron cristatum*) shows promise of having utility on the foothill and lower montane ranges of the West but so far seems to have been used chiefly in dry farming. This Siberian species is regarded by Woodward as the best forage plant thus far tried out at the Judith Basin substation, Mont. (*36*). Oakley and Westover (*21*) regard it as one of the most promising hay grasses for the northern Great Plains. It furnishes pasturage about two weeks earlier than the other grasses at Mandan, N. Dak., produces well, and is reported to be of good palatability (*31*). In recent range reseeding trials thin stands only were obtained at 7,400 feet elevation in the oak zone in central Utah and at 7,600 feet elevation in southwestern Colorado, and not more than a fair stand was obtained in the foothills of the Rocky Mountains in northern Colorado. This species did not do so well as common bromegrass in these localities.

SMILO GRASS

Smilo grass (*Oryzopsis miliacea*), often called millet mountain-rice, is a perennial European bunch grass, 2 to 3½ feet high, introduced in a few places in California. It is a good forage species. In a successful experiment on the Sierra National Forest, Calif., on a burned-over area, the seed was broadcast in the ashes and worked in with a brush after the oak slash had been burned and hogs had worked up the ground. By the following April a good stand was obtained, and a fair stand survived after 10 years, despite very heavy grazing and two fires.

BULBOUS BLUEGRASS

This Old World species (*Poa bulbosa*) has attracted considerable interest lately in western Oregon, where originally it was accidentally introduced. Its palatability is very good, but in that locality it is purely a winter pasture or range grass, being green from September or October until May or June, after which it hay cures and is readily eaten down by livestock. It is an aggressive species and reproduces from underground bulbs, from seed, and also from bulbs that are frequently formed in the inflorescence.

TALL OATGRASS

This large leafy Old World bunch grass (*Arrhenatherum elatius*) has become established in certain parts of the Pacific coast. It may have possibilities in lower range country where good moisture conditions obtain, but results with it thus far under range conditions are too meager to justify recommending it at this time.

CULTIVATED AND INTRODUCED SPECIES OF NONGRASSES

A number of foreign species of nongrasses, some accidentally established and others extensively cultivated in the United States, have been tried out in occasional range-reseeding tests. These exotic nongrasses include the following eight herbs: Red, white, and alsike clovers; white and yellow sweetclover; toothed bur clover or medic; alfalfa and alfileria; and one low shrub, Australian saltbush. The first three are adapted only to fairly moist sites; several of the others have done well on the range west of the Cascade Mountains in Oregon and Washington.

RED CLOVER

Red clover (*Trifolium pratense*) thrives best in rich, well-drained upland soils but tends to die out in a few years. About 10 to 12 pounds of seed per acre should be sown. Full details concerning cultivation and growth of this species for hay and pasture purposes are given elsewhere (*23*).

WHITE CLOVER

White clover (*Trifolium repens*), often called Dutch clover, grows especially well on the moist soils west of the Cascade Mountains and reasonably well on the fairly moist soils of other montane ranges at medium to high elevations. It will endure a great variety of soils but will not survive on very wet, very poor, or very shaded sites. It is easy to start and, unlike the other clovers in common cultivation, is long-lived and reproduces by creeping stems or stolons. The forage, rather small in quantity, is sweet, nutritious, and tender, and is greedily eaten. White clover is held in especial esteem for sheep. A serious drawback to general use of white clover in range reseeding is the fact that the seed is probably the most expensive of all the commonly cultivated forage species. About 6 to 8 pounds of seed per acre is used when it is sown pure, but the best results are obtained with mixed sowings. This species would doubtless do well wherever growing conditions are favorable.

ALSIKE CLOVER

This clover (*Trifolium hybridum*) has a shallow root system, with noncreeping stems and occasionally attains a height as great as 3 feet. It is particularly adapted to wet and cold places and will not withstand drought. Although in swales it will sometimes drive out sedges and aquatic grasses, some preparation to reduce competition is desirable before it is sown. Where drainage is improved, such species as Kentucky bluegrass will frequently invade the area and eventually are apt to supplant part of the stand. The herbage of alsike clover has a bitter taste and does not equal in palatability that of either white or red clover; nevertheless it is highly nutritious, chemical analyses of the air-dried hay showing percentages of crude protein varying from 10 to 13 per cent. It does not gather dust or become diseased so readily as does red clover, nor does it appear to cause bloat in livestock so readily as alfalfa and red clover. However, its exclusive use is known sometimes to cause ulcerations of mouth, forelegs, and body in horses and mules, a condition known as trifoliosis (*19*), but there appears to be some evidence that this disease is due rather to some fungus on the clover than to the host plant itself. The seed has high viability. About 6 to 10 pounds of seed per acre is used when it is sown pure, but it is best to use the species in mixture. Details concerning proper mixtures for cultivated pastures and hay are given elsewhere (*22*).

WHITE SWEETCLOVER

White sweetclover (*Melilotus alba*), sometimes called white melilot, makes excellent pasture for cattle, sheep, and horses when the animals have become accustomed to it. Originally the plant was not considered as having much value because of the bitter taste of the leaves and the tendency of the stems to become woody. However, livestock turned on to sweetclover pasture before more palatable clovers and grasses are up will soon acquire a taste for the species. If the pasture is kept grazed down fairly close the fresh leafage will tend to remain palatable and the stems tender and succulent. This species does not produce bloating so readily as alfalfa or red clover.

It has been demonstrated that sweetclover will thrive where the rainfall is only three-fifths of that required for normal growth of timothy and red clover (*4*). The species makes its best growth where lime is present but is not exacting as to soil and does well in compact soils with only enough stirring to get the seed covered. Being a biennial, or sometimes annual, and dependent upon seed for reproduction it will not survive after the second year where the growing season is too short or too dry for the seed to mature. Furthermore, although it is desirable to keep it grazed rather closely, enough plants must be permitted to go to seed each year to maintain the stand.

The species produces a very great amount of forage, as the plants are many-stemmed and 2 to 6 or more feet high. It is a vigorous grower, flowers throughout the growing season, and builds up the soil through the addition of nitrates. It is often observed that

other forage plants, such as Kentucky bluegrass, make better growth where sweetclover is present than when grown alone.

Although not as yet tried out extensively in experimental range reseeding, indications are that white sweetclover might do well under favorable western range conditions. Some stirring of the soil to get the seed covered is ordinarily essential for success in sowing white sweetclover, although sowing on sod ground has been done successfully in Montana (*16*). Hulbert (*12*) reports that a satisfactory stand usually can be obtained on dry slopes in Idaho by harrowing or disking in the early spring and broadcasting a few pounds of sweetclover seed to the acre, or by scattering seed when the soil is "honeycombed" in the early spring.

YELLOW SWEETCLOVER

Until comparatively recently yellow sweetclover (*Melilotus officinalis*) was relatively little used. Recent studies, however, especially at the Montana and Colorado Agricultural Experiment Stations, have greatly enhanced the popularity of yellow sweetclover, and in those two States at least it is considered to give better results under dry farming than the white-flowered species (*15*, *16*). The reasons for this preference are that yellow sweetclover has a finer texture than white sweetclover, is less stemmy, more leafy, matures a week or two earlier, and has ordinarily a greater spread which results in the production of more pods and more satisfactory perpetuation.

Yellow (as well as white) sweetclover has become naturalized on some western ranges but until very recently has rarely been sown artificially, partly because of a general feeling that livestock do not care much for it.

With yellow sweetclover, as with white sweetclover, some tilling of the soil is essential to get the seed covered.

Sweetclover, especially yellow sweetclover, has obvious advantages for forage. Among these are its great size and abundant leafage, rapid growth, large seed crop, vigor and ability to withstand heavy use, aggressiveness, very early growth, and tolerance of heat, drought, and poor soils. In addition, sweetclover is almost unequalled for soil nitrate enrichment and is a famous beeplant. The Colorado Agricultural College reports that sweetclover on nonirrigated farm lands in that State has been carrying from one to two head of mature cattle per acre for five to six months.

TOOTHED BUR CLOVER

This aggressive winter annual (*Medicago hispida*) is abundant and is an excellent spring forage on plains and foothills of western California, where it was accidentally introduced years ago. Its nutritive qualities are not much inferior to those of alfalfa, and, while its taste is somewhat bitter, livestock soon learn to relish it. The species may have promise in other regions of the West having the mild winter temperatures and other growth conditions characteristic of the California habitats where it thrives. Livestock relish all varieties. Typical toothed bur clover, because of the spininess of its pods, is more easily disseminated by livestock than the smoother-fruited forms, but since the value of the fleece is reduced

by the presence in it of these spiny pods, the sheepmen prefer the smoother varieties. McKee calls attention to the fact that, while this species does best on heavy but fairly well-drained loams, it will grow in almost any soil, even if somewhat alkaline, provided it is not too arid, and will withstand wide variations of moisture, soil texture, and shade (*18*).

ALFALFA

Alfalfa (*Medicago sativa*) is regarded as second only to timothy as a forage crop in North America. It is especially adapted to warm, fairly dry regions with a deep soil, preferably of limestone origin, although some hardy varieties such as Grimm will withstand cold as low as −20° or −30° F., provided it is dry. Heavy tillage, such as plowing and harrowing, is necessary to get alfalfa established, and the species has been little used in artificial range reseeding. Tests made have generally proved unsuccessful, but breeding experiments with certain strains give promise of developing races of this choice legume that will prove suited to the adverse growing conditions of portions at least of the western range.

ALFILERIA

"Filaree" (*Erodium cicutarium*) is an excellent forage in years of good rainfall in many parts of the arid Southwest and in portions of California. It was brought in from the Old World, presumably from Spain and Mediterranean region, and has spread naturally over much of the Southwest and as far north as central Idaho. Alfileria begins growing during the winter rainy season, and at that time, if moisture is sufficient, furnishes an abundance of highly valuable green forage. When this moisture is dissipated the plant dries up but often remains edible and palatable until utilized. Sampson (*28*) found that nearly 30 per cent of the early reseeding experiments with this species gave good results. The seed must either be exposed to the weather for several months or the seed coats broken in order to induce satisfactory germination. Thornber (*33*) calls attention to the fact that establishment of alfileria stands from seed sowing is likely to prove a rather slow process. Probably this species is of most value for reseeding areas similar to those where it has gained a foothold naturally or where it is likely to spread. Sampson recommends fall sowing with 8 pounds of seed per acre at elevations not exceeding 5,000 feet in California or 3,000 feet in the North.

AUSTRALIAN SALTBUSH

Australian saltbush (*Atriplex semibaccata*) was introduced throughout the semiarid section of the United States about 30 years ago. The high hopes once held for this plant for improvement of the range in dry, alkaline regions of the West have fallen somewhat short of realization, for the species has proved a failure except in specific areas along the Pacific coast, in the San Joaquin and Imperial Valleys of California, and in the Salt River, Yuma, and Santa Cruz Valleys of Arizona (*17*, *20*). In these regions it has become well established as a good range plant, producing herbage during a season when other forage plants have dried up.

NATIVE GRASSES

It seems reasonable to suppose that native or wild species are naturally better adapted to the growing conditions where they occur than any cultivated species could be and that it would be a wise plan to undertake range improvement by sowing the seed of the better native forage species. The practicability of using these native species in artificially reseeding depleted range lands depends, however, upon the availability of good seed at reasonable cost. The seed of only one of our native forage species, slender wheatgrass (*Agropyron tenerum*), is obtainable on the market at the present time. Collection of the seed of the others on the range is usually rather expensive, and the seed is apt to produce a very low percentage of plants. It is obvious that future use of these native species in artificial reseeding will largely depend on what may be done toward quantity production, at a reasonable cost, of satisfactorily viable seed. The determination as to which native range plants give promise for cultivation is a wide field for study and one in which relatively little work has as yet been done, either by individuals or by governmental agencies. Some of the results thus far obtained are, however, rather encouraging.

Investigations by the Forest Service have been concentrated largely at the Great Basin branch of the Intermountain Forest and Range Experiment Station in the Wasatch Mountains of central Utah and at the Fort Valley branch of the Southwestern Forest and Range Experiment Station in northern Arizona. In all, about 45 species, mainly grasses, have been tested.

BIG MOUNTAIN BROMEGRASSES

The big mountain bromegrasses (*Bromus carinatus*, *B. marginatus*, *B. polyanthus*, and *B. subvelutinus*) are very closely related and for practical purposes are treated here as a unit. These bromegrasses are almost universal in the cooler, moister montane areas of the West; all are perennials, without rootstocks but with deeply seated masses of fibrous roots; all have copious leafage of good quality, produce an abundance of good seed, and provide excellent forage for cattle, sheep, and horses. They grow at elevations of 5,000 to 10,000 feet, in moderately moist to moderately dry clay loam and sandy loam soils. Extensive tests at the Great Basin branch station with *B. marginatus* and *B. polyanthus* show that the plants make fair growth at 7,200 feet elevation where the average annual precipitation is about 18 inches and make excellent growth at elevations between 8,000 and 10,000 feet where the precipitation is 12 inches more. (Pl. 2, A.) They produce a good stand by the second year after seeding. These two species have the advantage of being able to grow in rather poor, depleted soil. Although all the bromegrasses are easily killed out by continued close grazing they hold up and continue to produce well under any rational system of cropping. When cut as hay on good soils, they have yielded as high as 2 tons per acre; on poorer soils, of course, the yield is less. Recent tests with *B. carinatus* and *B. subvelutinus* show approximately equal results.

Seed of these native bromegrasses is not obtainable on the market at the present time but may be produced with comparative ease and little expense. Yields as high as 425 pounds to the acre have been obtained under cultivation on mountain land without irrigation, where the precipitation is about 30 inches per year. The seed has been harvested for as low as 4 cents a pound, which, together with the original costs of the parent seed crop and of planting, makes a net cost of approximately 6 cents per pound, exclusive of transportation charges. Many sheepmen of central Utah have their herders collect seed in the fall of the year on areas upon which grazing has been deferred until seed maturity. About 20 pounds of seed should be sown to the acre.

At least one species (*B. polyanthus*) is attacked to some extent by a smut (*Ustilago bromivora*), which may or may not be a factor in the use of plants of this genus. This disease destroys the seed, although it does not appear to decrease materially the production of leaves and stems on infected plants. Only a relatively small number of specimens were attacked in the native habitat of the plant in central Utah, but about 60 per cent of the stand was infested when grown under irrigation in the warmer drier valley at the Utah State Agricultural Experiment Station from seed collected in its native habitat. This smut undoubtedly attacks other species of Bromus and is a problem needing additional study.

VIOLET WHEATGRASS

This species (*Agropyron violaceum*), one of the most palatable of the true wheatgrasses, is a member of a native genus famed for its highly nutritive qualities. Although without rootstocks, violet wheatgrass is persistent, as it is a deep-rooted, thick-tufted perennial. Its stocky, leafy growth and freedom from awns or beards enhance its range value. It grows naturally on fairly dry sandy loam soils, usually in parks or open forests at high or medium elevations in the western part of the United States, from Washington and northeastern Oregon to the Rocky Mountain region and as far south as northern Arizona. It is ordinarily sparsely distributed on the range but in some localities occurs in considerable abundance. Although it is somewhat more exacting as to soil than the big mountain bromegrasses, the two often occur together in the better soils. In such sites violet wheatgrass will as a rule eventually dominate the bromegrasses because of its more persistent growth, slightly lower palatability, and greater resistance to grazing. Although in its native state violet wheatgrass is usually but sparsely distributed, it responds well to cultivation. (Pl. 2, B.) Where the ground was plowed before seeding, yields of violet wheatgrass hay as high as 1.25 tons per acre have been obtained in a season on mountain range. The seed crop is lighter than that of bromegrass, and consequently the seed is more expensive. Seed has been produced for 16 cents a pound, but improved methods of harvesting would doubtless result in a material reduction of this figure. Fifteen to twenty pounds of seed should be sown to the acre.

SLENDER WHEATGRASS

This species (*Agropyron tenerum*) is the most widely distributed of our native Agropyrons and occurs in dry mountain meadows, along mountain valleys, and in other medium-moist, well-drained situations. Cattle and horses will readily eat practically the entire aerial portion of slender wheatgrass and thrive upon it. It is well suited to sheep up to about the time of flowering, when the leafage becomes somewhat harsh. In late summer sheep greatly relish the grain, which, if mixed with more succulent feed, aids in putting on hard, substantial fat. Later in the fall and winter the dried herbage affords winter grazing. As a range forage grass whose seed is procurable in the market, slender wheatgrass deserves consideration because of its early growth and maturity, good palatability, very good nutritive qualities, good crop of viable seed, alkali tolerance, and virtual freedom from awns or beards. It seems to be the best perennial grass known to be adapted to dry-land conditions, with the exception of common bromegrass, and it is extensively cultivated in the northern Great Plains for hay and paturage (*25*). Slender wheatgrass is an exceedingly variable species, extreme forms being difficult to separate on the one hand from bearded wheatgrass and on the other from violet wheatgrass. It affords, therefore, attractive possibilities for selective breeding.

The forage value and wide distribution of this species and the comparative ease with which it may be established indicate that it has great possibilities for future range improvement if an adequate seed supply at low cost can be made available.

OTHER WHEATGRASSES

Several other species of wheatgrass are worthy of extensive trial on range lands. These include blue-bunch wheatgrass (*Agropyron spicatum*), bearded wheatgrass (*A. caninum*), bluestem (*A. smithii*), streambank wheatgrass (*A. riparium*), and thickspike wheatgrass (*A. dasystachyum*). The first two are bunch grasses, whereas the other three have rootstocks.

Blue-bunch wheatgrass was formerly one of the most important forage grasses in the foothills and adjacent valleys, plains, and mountain slopes throughout the Columbia Basin and Great Basin in Oregon, Washington, Idaho, Nevada, and Utah. It occurs throughout the sagebrush belt, on open dry hills and mountain slopes and timbered mountain slopes up to 8,500 feet. On millions of acres of open public domain and other range land where grazing has not been properly regulated it has succumbed to overstocking and too-early grazing. It has practically disappeared from much of the sagebrush type where such use has prevailed, being replaced by downy chess (*Bromus tectorum*), an annual of little value for grazing except for a relatively few weeks in the spring. Blue-bunch wheatgrass is an especially valuable grass on spring, fall, and winter range for cattle, horses, and sheep, and cattle and horses graze it throughout the summer as well. Its drawbacks are its lack of high resistance to grazing and its poor seed production, particularly on the drier sites. These characteristics necessitate judicious range management. Artificial reseeding to establish an early stand

has been tried out with fair success. The adaptability of the species to adverse dry conditions under which few other grasses will grow at all abundantly and its high forage value throughout the year warrant more extensive trials to develop a better seed-producing and grazing-resistant strain by careful breeding and selection.

Bearded wheatgrass, although seldom occurring abundantly, is one of the most widely distributed of the wheatgrasses, ranging throughout the central and northern part of the United States into southern Canada, where it occurs mainly in stream bottoms and on moist slopes. It is valuable for all classes of livestock. The few trials indicate also some promise for reseeding.

Bluestem is very abundant in the Great Lakes and eastern Rocky Mountain regions as far south as Arizona and New Mexico. It also extends across the western part of the United States to west-central California. It reaches fairly high altitudes but is more abundant on well-drained bottom lands, open plains, bench lands, and hillsides throughout its range. It is a very good forage plant while green and cures well on the ground for fall and winter feed. In the northern Great Plains region areas of bluestem are frequently reserved for final use by cattle before shipment to market. Bluestem is only a fair seed producer, but it spreads vigorously by means of its creeping rootstocks. A considerable number of trials indicate that it is well adapted to artificial reseeding.

Streambank wheatgrass is naturally a frequent associate of slender wheatgrass but is probably nowhere so abundant and apparently does not occur south of Colorado. It is usually rather smaller than slender wheatgrass and has smaller spikes. Its numerous rootstocks serve further to distinguish it.

Thickspike wheatgrass also occurs only as far south as Colorado but has a wider range than most of the other wheatgrasses, especially in sandy soils. It is found on the lower dry plains in central Idaho and up to at least 10,000 feet above sea level in the Wasatch Mountains.

Streambank and thickspike wheatgrasses are at least fair forage plants, although their tendency to become wiry as the growing season advances lowers their palatability, especially for sheep. Once established, they continue to spread by their creeping rhizomes or stolons and thicken in stand.

LITTLE-TRIED SPECIES

CULTIVATED BUNCH GRASSES

Among other cultivated bunch grasses which may have potential utility for reseeding on certain western ranges may be mentioned Dallis grass (*Paspalum dilatatum*) for warmer regions; the annual Sudan grass (*Andropogon sorghum sudanensis*) for semiarid conditions; perennial ryegrass (*Lolium perenne*) where soil is moist but well drained; and meadow foxtail (*Alopecurus pratensis*) and velvet grass (*Notholcus lanatus*) for regions both humid and cool, but insufficient work has been done to determine their true range value. Meadow foxtail often produces short rootstocks but is essentially a bunch grass in its usual growth habit. There are indications that velvet grass is an aggressive species in localities to which it is fitted,

but this advantage is at least partially offset by it hairiness, which makes its palatability to domestic livestock inferior. Notes on all five of the above species as cultivated pasture and meadow plants will be found elsewhere (*24*, *25*).

CULTIVATED CREEPING GRASSES

Bermuda grass (*Capriola dactylon*, syn. *Cynodon dactylon*), the original "grama" of the Spaniards, known also as dogtooth grass, has become naturalized in parts of Arizona and elsewhere in the Southwest. It covers several thousands of acres around the Roosevelt Reservoir on the Tonto National Forest, Ariz., where it follows closely the rise and fall of the water level and furnishes the greater part of the pasturage for the cattle grazing near the lake. For range reseeding Bermuda grass is adapted only to moist sites in a warm climate.

Among other cultivated creeping grasses which may perhaps be worthy of further experiment in reseeding portions of the western range may be mentioned carpet bent, often called creeping bent (*Agrostis stolonifera*); rough bluegrass (*Poa trivialis*), which has become established on a number of ranges in Washington and Oregon; red fescue (*Festuca rubra*, vars.), native forms of which occur in the western mountains; Johnson grass (*Holcus halepensis*) in the Southwest; and reed canary grass (*Phalaris arundinacea*) in the North and Northwest. The use of these grasses for cultivated pasture is discussed elsewhere (*24*, *25*).

MISCELLANEOUS NATIVE PLANTS OF THE NORTHWEST

Preliminary trials have been made with a number of other grasses as well as a few weeds (nongrasslike herbaceous plants) with varying success. Porter brome grass (*Bromus porteri*), sometimes called nodding bromegrass, resulted in a fair stand but did not compare with the large mountain bromegrasses. Tufted hair grass (*Aira caespitosa*) and Wheeler bluegrass (*Poa wheeleri*) produced poor stands. Idaho fescue (*Festuca idahoensis*), green fescue (*F. viridula*), also known as mountain bunch grass, alpine fescue (*F. brachyphylla*), green needle grass (*Stipa viridula*), and western needle grass (*S. occidentalis*) all proved failures. Of the weeds, Browns peony (*Paeonia brownii*) and carrotleaf (*Leptotaenia multifida*) became established from the original seeding but would not reproduce, when seed collected in the Sawtooth Mountains in Idaho was sown on the Wasatch Plateau in central Utah. Sweet anise (*Osmorhiza occidentalis*), also known as western aniseroot or sweet cicely, Utah sweetvetch (*Hedysarum utahense*), and a lupine (*Lupinus* sp.) did not respond when sown in their natural habitat in Utah.

NATIVE GRASSES OF THE SOUTHWEST

Included among the most important forage grasses native in the mountain grazing lands of the Southwest are Arizona fescue (*Festuca arizonica*), beardless pine grass (*Blepharoneuron tricholepis*), black dropseed (*Sporobolus interruptus*), blue grama (*Bouteloua gracilis*), squirreltail grass (*Sitanion hystrix*), deer grass (*Epicampes*

rigens), mutton grass or Fendler bluegrass (*Poa fendleriana*), mountain muhly (*Muhlenbergia montana*), Porter bromegrass (*Bromus porteri*), side oats grama (*Bouteloua curtipendula*), and spike muhly (*Muhlenbergia wrightii*). All these species have been tried out in a limited way at the Fort Valley branch of the Southwestern Forest and Range Experiment Station on the Coconino Plateau in northern Arizona. The original sowings were made in 1913, and the results were noted from year to year through 1926. The seeded areas were not grazed throughout the period.

The trials were made in a typical bunch-grass type under western yellow pine and high in elevation for blue grama or spike muhly. Mountain muhly, beardless pine grass, and Arizona fescue grow naturally in the type. In general those species which are naturally more common in the immediate vicinity of the experimental plots have shown the most promise.

Mountain muhly did the best of all the species experimented with, seeding satisfactorily and maintaining a good stand of about 50 per cent ground cover. The older clumps in 1926 were dying at the center but growing outward along the periphery.

Beardless pine grass seeded well, but after 13 years the stand was rather thin. This species proved less aggressive than mountain muhly, which has invaded its areas.

Arizona fescue came in well, reached average height, but has had rather light seed crops and has thinned materially.

Blue grama and spike muhly started out as a few scattered clumps; the grama increased hardly at all.

Squirreltail grass seeded well at the start but gradually died out, and there were very few specimens of it left at the last observation.

Porter or nodding bromegrass came in well at the start and invaded adjacent range here and there, but only scattered plants survived.

The other species either failed to come in satisfactorily or died out readily. The chief obstacles to reseeding many of these native southwestern forage species are the apparently low viability of seed and the difficulty of obtaining seed. The rate of germination of the seed is shown in Table 2.

TABLE 2.—*Rate of germination of 11 native southwestern grasses, 1913 and 1915*

Species	1913	1915	Species	1913	1915
	P. ct.	*P. ct.*		*P. ct.*	*P. ct.*
Arizona fescue	40.6	----	Mutton grass or Fendler bluegrass	4.6	34.0
Beardless pine grass	8.4	----	Porter or nodding bromegrass	69.8	83.6
Black dropseed	19.8	----	Side oats grama	6.8	----
Blue grama	3.6	13.4	Spike muhly	32.8	----
Deer grass	17.2	----	Squirreltail grass	79.2	----
Mountain muhly	34.8	----			

With the exception of squirreltail grass and Porter bromegrass, the rate of germination in the two tests was low, indicating that much of the seed was not fertile.

In general, artificial reseeding tests with native and cultivated plants on the range in southern Arizona have thus far been distinct failures, except perhaps where there is summer flooding of the areas (*9*, *10*, *11*, *34*).

SEEDING TO MIXTURE

Because of differences in cost and behavior it is often a good plan to sow two or more species in mixture. Kentucky bluegrass, for example, is expensive and slow in getting started. Once under way, however, it is one of the most desirable plants to have on the range. Timothy, on the other hand, becomes established more readily, yields a fair return soon after seeding, and is much less expensive than many other species. However, it is not so well able to reproduce and maintain its stand under range conditions as is Kentucky bluegrass. Consequently the cost of seeding may be kept down, earlier returns obtained, and maintenance of cover insured if two species such as these are sown in mixture. By the time the less aggressive species thins out the more persistent will have established itself and be producing well.

The mixtures to use differ with the growing conditions. On the higher, more moist mountain areas where the growing season is short, common bromegrass, Kentucky bluegrass, and Canada bluegrass have given good results when sown in mixture with timothy or some other bunch grass. The bunch grass may not be expected to revegetate at such high elevation, but it becomes established early and will not check the spread of the creeping grasses. Redtop and alsike clover also can well be included in such mixtures for use on the moister situations. Orchard grass is best adapted for use in a mixture for seeding at the middle or lower elevations where the growing season is not too cool or too short and where there is ample moisture for this species.

On drier situations, common bromegrass in mixture with slender wheatgrass or some one or two of the other more drought-resistant bunch grasses should give the best results. Common bromegrass, in combination with sweetclover and slender wheatgrass, is recommended by the Colorado Agricultural College (*15*) for use on nonirrigated farm lands where the precipitation is from 12 to 18 inches. It is suggested that equal parts by weight of the three species be used in making up the mixture. On fall-plowed land this combination should be sown at the rate of 10 to 15 pounds per acre.

More study is needed as to the proper quantities of each kind of seed to use in mixtures for range lands. However, indications are that when the more expensive and long-lived species, such as common bromegrass or Kentucky bluegrass, are used in mixture with a plant like timothy, a good plan is to use one-half the amount by weight ordinarily used when one of the two former species is sown singly, together with from three-fourths to the full amount of timothy used when sown by itself. When plants with similar growth habits, such as timothy and orchard grass, are sown together, one-half the amounts recommended for each for pure sowing should be used. If plants with light seed are to be used in combination with species having heavier seed it may be necessary, in broadcast sowing, to sow each kind of seed separately in order to get a well-mixed stand.

IRRIGATED-PASTURE MIXTURES

Where irrigated land is available for feed production as a supplement to range land, it may be found profitable to put part of it in

pasture. Such pastures will furnish an abundance of feed at low cost. Information on irrigated-pasture mixtures may best be obtained from the western State agricultural colleges. One of the combinations known as "Morton's mixture" is reported by the Colorado Agricultural College to give very good results in that State when used on well-drained irrigated soils at Fort Collins (*15*). Seeding of this mixture is recommended at the rate of 30 to 50 pounds per acre on a well-prepared seed bed. The recipe, on a 50-pound basis, is as follows:

	Pounds
Common bromegrass	15
Orchard grass	15
Meadow fescue	10
Timothy	6
Yellow sweetclover	4
Total	50

For wet lands the following mixture and amount per acre is recommended:

	unds
Redtop	10
Timothy	6
Alsike	4
Total	20

Some of the irrigated pastures so sown are reported to have a grazing capacity of two to three head of mature cattle per acre for four and one-half to six months. This is equivalent to the production of from 5 to 8 tons of hay per acre without any cost for putting up the hay and feeding it. Other pastures are grazed for a period in the spring before the summer range is ready for use. When so used the subsequent growth produces 1 to 2 tons of hay in addition to considerable fall grazing after the hay is cut.

THE BEST TIME TO SEED

In choosing the time of year to seed, the most important consideration is that there shall be an ample supply of soil moisture from the time of germination of the seed until seedlings have become fairly well established. Where a dry period is likely to occur during the summer months it is best to sow long enough before this period to allow the seedlings to develop root systems that will enable them to survive the drought. It may be just as well to sow near the close of the dry period, if the number of growing days immediately following it is sufficient to permit the establishment of the plants. Shallow-rooted seedlings are apt to suffer when the soil gets dry, whereas the deeper rooted plants are much better able to withstand such conditions.

Late fall sowing has given the best results in the Wallowa Mountains of northeastern Oregon, in the mountains of the Pacific northwest generally, and in the Wasatch Mountains of central Utah. This seems to be correlated with the short growing season of the higher elevations of those regions and the uniformly good moisture conditions following the melting of the winter's snow in the spring. However, in the high mountain ranges of the Utah region sowing just before the advent of the more copious moisture of midsummer has

given almost as good results in many instances as fall sowing. In the regions mentioned, seedlings from early spring sowing usually do not develop a root system adequate to sustain them through any protracted dry spell, whereas seed that was sown late in the fall and allowed to lie dormant during the winter and to work into the ground to some extent germinates as soon as the snow melts, and the seedlings have well-developed root systems by the time a dry period occurs. Seeding in the fall, however, must be done sufficiently late to prevent germination taking place until spring; otherwise losses may occur from heaving of the soil or winterkilling. The seed of species with highly impermeable seed coats, like alfileria, for example, have an extended period of dormancy, and it is necessary for the seed to "weather" through the winter to germinate well.

If the soil of the area to be reseeded is saturated most of the year, late fall sowing should be avoided lest the seed decay before germination can take place the following spring.

Tests indicate that the time for sowing is especially important in the Southwest, where precipitation is largely seasonal and often local and erratic, and where the season of favorable growing temperatures is long. In fact in this region time of sowing seems to be the most important single controllable factor. A few successes have been obtained with fall (October) sowings, but in reseeding tests success has been achieved in the greatest number of cases with late spring seedings, and the greatest number of failures have followed midsummer (August) sowing. In this region the best results so far have been obtained by taking advantage of the favorable germinating conditions obtaining when the early summer or the occasional late spring rains have begun, after the spring drought has ended. Seeding should, however, be done late enough so that rodents will not eat the seed before it has a chance to germinate. The seedlings, if precipitation is normal, usually attain sufficient development to withstand unfavorable fall conditions.

In general, spring sowing will give good results where the site remains moist throughout the summer, and fall sowing is preferable where a summer drought is to be expected.

SOWING AND SOIL TREATMENT

In range improvement by artificial reseeding the seed must be satisfactorily distributed by some means over the area to be sown and also be brought into sufficiently close contact with the soil to insure good germination and a reasonably even stand. At the same time the cost should not exceed a conservative estimate of the returns to be obtained. The methods used must be justified by the value of the increase in carrying capacity of the range.

In scattering the seed, both hand broadcasting and sowing with the farmer's small hand seeder are economical and effective. The hand seeder requires less practice in getting the seed evenly scattered, but an experienced man can obtain as good results by hand broadcasting. The procedure should be the same on the range and in the farm pasture. Drilling in the seed is sometimes justified where the ground has been plowed and fully prepared.

Since in range reseeding the principal item of expense is usually the seed, it is often sound economy to employ some inexpensive method of preliminary tillage that will insure a satisfactory proportion of the seed getting into proper contact with the soil and will reduce the native vegetation sufficiently to free the seedlings from unnecessary competition. In the case of sweetclover some preparation of the seed bed is absolutely indispensable.

Methods of soil preparation include full tillage by plowing, plowing of contour furrows, harrowing with a steel-tooth, wooden-peg A, or brush harrow, and trampling by sheep. The method to choose depends upon the accessibility of the area to be seeded, the availability of the implements or other means, the thoroughness of planting that is justified, and the local soil and vegetative conditions.

The most economical practice under customary range conditions is to go over the ground once with a harrow after sowing. Plowing, whether or not it is followed by harrowing or other intensive methods of tillage, is justified only on the very best range areas where early returns and heavy yields may reasonably be expected.

Where such intensive treatment is employed, a higher germination of seed is usually obtained and a good stand becomes established earlier than where methods are less intensive. Where plowing is justified, a heavy soil requires deeper plowing than a light one, and annual vegetation or most perennials with rootstocks are obliterated by a shallower cultivation than is effective for deeper-rooted species. As the seed must not be too deeply covered, it is advisable to use a press drill or similar equipment where seeding is done on fully tilled soil.

Plowing contour furrows 3 to 4 feet apart at right angles to the slope of the land, followed by harrowing or brushing in the seed after sowing it over the furrows, has been employed occasionally on the range. Where tried on sagebrush land this method has been found to be satisfactory and relatively inexpensive. Such plowing can be done in spite of a fairly heavy stand of shallow-rooted brush species, open stands of more persistent shrubs or trees, or considerable rock outcrop. The furrows should be plowed parallel to the contour of the slopes, in order to catch and hold the run-off from heavy rains and melting snows; otherwise, instead of being retained on the ground, the water will gather in the furrows, run off, and cause erosion. If properly done, the plowing prepares a good seed bed, opens up the stand of native vegetation, and enhances the moisture supply. This method results in only a partial stand the first two or three years, since the unplowed portion is not sown but must be filled in by the spread of the plants from the furrows. Consequently plants that mature and disseminate seed or spread vegetatively must be used.

On the average or less desirable range sites thorough plowing is seldom, if ever, economical. Although the seed may germinate better, this temporary benefit is outweighed by other considerations. In the first place the stand of cultivated plants soon thins out to what the soil naturally can support, and the eventual density is frequently no greater than if less intensive methods of cultivation had been followed. Furthermore, such thorough tillage requires total

exclusion of livestock until the soil has settled sufficiently to endure trampling, and the value of the native vegetation which was destroyed by the plowing is lost. These considerations, together with the high cost and difficulty of plowing areas abounding in rocks and brush, make harrowing the most practical expedient, except on those exceptional sites where optimum conditions of soil, surface character, and yield expectancy obtain.

Harrowing is ordinarily done but once—after the seed has been sown. This is ordinarily sufficient where the ground is not unduly compacted. It is doubtful if, under range conditions, a double harrowing—before and after sowing—is ever sufficiently advantageous to justify the extra cost involved. On very loose soils it may be preferable not to use the harrow at all, lest the seed be covered too deeply.

Where harrowing is employed to cover the seed or to stir the soil somewhat the farmer's ordinary steel-tooth harrow may be used to

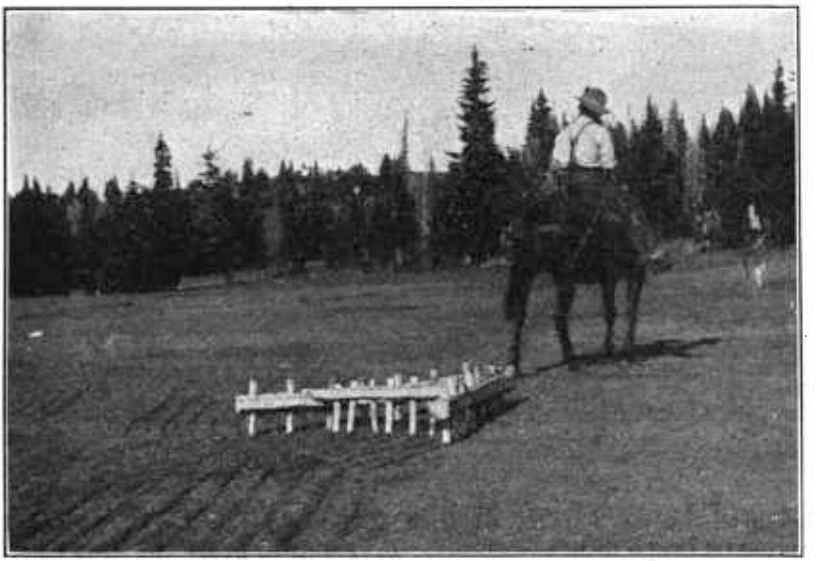

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FIGURE 2.—A wooden-peg A harrow, made of alpine fir, used effectively in an artificial reseeding near timber line, Wallowa National Forest, Oreg.

advantage. Transportation facilities or the kind of ground surface to be treated may, however, govern to some degree. The use of this type of harrow presupposes that the area to be sown is accessible by team and wagon and that the ground to be planted is reasonably clear of rank vegetation, rocks, or other objects which prevent the harrow teeth from reaching the ground.

The roughly constructed wooden-peg **A** harrow may be used under much the same conditions as the steel-tooth harrow and has the advantage of not having to be transported long distances. The only tools needed to construct the wooden-peg **A** harrow wherever materials are available are an ax and an auger or brace and bit.

The wooden-peg **A** harrow which is dragged by a rope attached to the saddle horn (fig. 2) consists of a framework of three logs, each

5 or 6 inches in diameter cut into lengths of about 5 feet, fitted together in the form of the letter A, or a triangle, with wooden pegs at intervals of about 5 inches made from branches of available timber or small saplings fitted into holes bored in the log.

The brush drag, or brush harrow, also useful for covering seed in loose soil free from vegetation, consists of several broomlike branches or saplings of stiff-twigged or stiff-leaved species, in lengths of about 6 feet, laid parallel to each other and tied by the butt ends to a crosspiece about 6 feet in length. It may also be dragged by a rope attached to the saddle horn.

Driving a band of sheep two or more times over an area after the seed has been sown or grazing them on it in compact formation is a very satisfactory and inexpensive method of working the seed into the soil (fig. 3), especially where the soil is stiff, the area partially

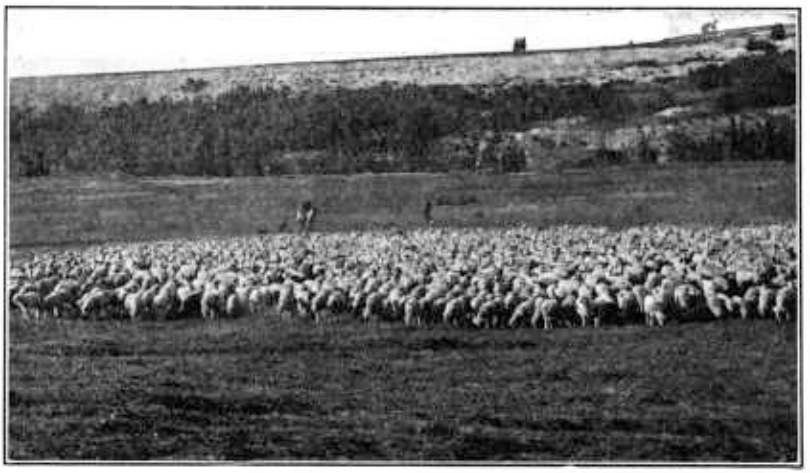

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FIGURE 3.—Sheep, compactly herded, trampling in seed on an artificially reseeded area, Manti National Forest, Utah

vegetated, or the surface of such a character that the use of the harrow or brush drag is difficult. It is well to graze the area closely enough to loosen the soil and the turf of native plants and allow the seed to be worked in. Where the soil is already loose or moist, however, care must be used to see that the trampling does not continue long enough to get the seed too deeply in the ground or to pack the soil severely. Cattle may be used in a similar manner, but they are more difficult to handle.

SOWING AND PLANTING TO CHECK EROSION

Closely akin to range improvement by artificial reseeding is the sowing and planting of grasses, weeds, shrubs, and trees for the purpose of checking soil erosion. When the natural plant cover on the headwaters of streams in mountainous country has been depleted by overgrazing or other cause, erosion usually sets in immediately. A system of small rills or shoestring gullies ordinarily becomes established on the upper slopes of the watershed with sheet erosion taking place between them. (Fig. 4.) Farther down the

slopes these rills join to form larger gullies that finally empty into the natural drainage channels. Erosion of this character does much damage by depleting the soil on the mountain slopes, adding sediment to the streams, and hastening surface run-off even to the extent of contributing materially to the size and destructiveness of floods (*1*, *7*, *30*). Where the natural plant cover has been reduced to a point beyond which erosion control through natural revegetation can not be expected within a reasonable period, either under carefully managed grazing or complete exclusion of livestock, erosion should be checked by planting or sowing, wherever such action is warranted by the values involved.

F-223116

FIGURE 4.—Shoestring gullies formed by abnormal erosion on a mountain watershed. Such erosion may be checked by judicious artificial reseeding

A number of species, including native grasses, weeds, and shrubs, one tree species, and several tame grasses, have been tested at the Great Basin branch of the Intermountain Forest and Range Experiment Station for checking erosion on high mountain watersheds of the Wasatch Plateau in central Utah. These lands had been badly depleted because of overgrazing prior to 1910 and were seriously eroded. The methods used included the seeding of grasses and two shrubs on eroded areas and hillside terraces and the transplanting of grasses, weeds, and shrubs to terraces and gully sides. In a few tests, shrubs were transplanted a few feet apart in rows paralleling the hillside contours. These experiments were made on watersheds between 9,000 and 10,000 feet elevation, over a period of nine years, beginning in 1913. Results were observed up to 1928.

Of the species tried out, several native grasses, when seeded broadcast over the eroded areas, gave the best results. Following the seeding, new plants became established in the fine soil that had accumulated in the gullies as a result of wind and gravity. Here also more favorable moisture conditions obtained than on the more exposed surfaces between the gullies. After a few plants had become firmly rooted the stand gradually thickened, until in a few years the gullies were clogged with vegetation. Moreover, the plants spread out gradually over the intervening areas. The velocity of the run-off in the gullies was greatly diminished because of the established vegetation, and the sediment carried in the water was deposited back of the tufts of grass. No further cutting occurred in the gullies, save when the run-off from an occasional, extremely torrential rain caused some washing of the soil on gully sides where vegetation had not yet gained a foothold. Where the vegetation had spread between the gullies, the run-off was still further checked, and after 30 to 50 per cent of this surface had been occupied by plants, little or no erosion took place, and gradually the gullies began to disappear. The seedlings had only the interval between times of heavy run-off in which to become established, and when run-off occurred before they were well rooted the plants were washed out. However, years without extreme run-off occurred frequently enough for most plantings to succeed with the first attempt, and in no instance were more than two replantings necessary.

Obviously, under any method, some productive soil must be available to sustain the seedlings. Where the soil has been partially depleted the plants least exacting as to soil requirements, handled with the special methods necessary, will give the best results. In cases of extreme erosion and complete removal of the productive surface soil or on "bad lands" where soil has had no opportunity to form, it may be necessary to improve the soil before planting to any species thus far experimented with will be successful. Where the native vegetation has been destroyed but the soil has not been depleted materially and not many gullies have been formed, any species suited to the local climate and soil may be planted. Higher costs are usually justified for protecting a watershed against erosion than when the planting is for forage production alone.

SEEDING ERODED LANDS

SELECTING THE PLACES TO SEED

The best time to check erosion is in its incipiency. If this has not been done and the cutting process has progressed until the gullies are more than 6 inches wide at the top and 3 to 5 inches deep, it will be best to begin work on the higher portions of the eroding area where the gullies are smaller, or possibly between the gullies if soil and moisture conditions there are favorable to the establishment of seedlings. Even the quick-starting and more rapid growing species seldom become established at the outset in the larger gullies, where the run-off is usually very heavy following torrential rains or rapid melting of snow. Once the smaller feeder gullies and the spaces between them on the upper portion of a slope have been revegetated, the run-off into the larger gullies below will be

checked to a point where seeding in them will be successful. In fact, if the species selected has strong seeding habits suitable to the growing conditions, it will spread down the slope of its own accord as rapidly as improvement in conditions will permit. Consequently, judicious sowing on the upper limits of an eroded slope may eventually reclaim the entire slope except as soil may interfere at the lower portions with the spread of the particular species used. The process will usually be slow in the deeper, larger channels but may be hastened by engineering works such as dams and tiling, or by plowing or planting (*27*).

SPECIES

In sowing to check erosion prompt establishment of the species has been shown to be essential since the seeding must gain a foothold between the times of torrential run-off. Quick-starting, rapid-growing, strong-rooted species that reproduce readily by seed, rootstocks, or stolons should be selected. With a strong root system to bind the soil and resist heavy run-off, and strong reproductive qualities to extend as rapidly as possible the area thus held, the first victory is won in the process of revegetation. (Fig. 5.)

Mountain bromegrass, meadow barley (*Hordeum nodosum*), and violet wheatgrass, all native grasses, ranked in the order named in checking erosion in tests on the Wasatch Plateau in central Utah. Although none of these species have rootstocks or stolons, they spread readily by seed, have strong, deep root systems, and are well adapted to the growing conditions obtaining in that locality. Violet wheatgrass is somewhat slower to become established and requires better soil than the other two species named. Meadow barley is the least desirable of the three, if grazing subsequent to the checking of erosion is contemplated, as it is the least highly prized for forage. Seedlings of Letterman needle grass (*Stipa lettermani*), Nevada bluegrass (*Poa nevadensis*), greenleaf fescue (*Festuca viridula*), thickspike wheatgrass (*Agropyron dasystachyum*) bunchberry elder (*Sambucus microbotrys*), and squaw currant (*Ribes inebrians*), all native species, were tried out, but each of these plants was found unsatisfactory because of difficulty in getting started from seed or inability to become established quickly.

Of the cultivated species tried out, common bromegrass has given the best results. It is slower in becoming established than the better native plants and consequently gives best results on the more moderate slopes. Once established, it spreads fairly rapidly by rootstocks, making a dense turf and eventually forming an excellent protective covering. Kentucky and Canada bluegrasses have many of the same qualities when once established but are slower than bromegrass in gaining a foothold. Where these species grow well, they deserve consideration for use in follow-up plantings after the worst erosion has been checked by more rapid-starting plants. Orchard grass and timothy proved of little value in checking erosion at high elevations, because of their slow rate of establishment and inability to revegetate.

The sowing of a luxuriant, rapidly growing annual will often serve where the period between times of run-off or disturbance of the soil is too short for perennials to become established. This often occurs in warm, dry sites where the moist season is too short for the

rapid development of perennial plants. Downy chess or bromegrass is valuable for use as a first aid in this way. It starts very quickly and grows rapidly during the brief wet period following the melting of the snow or during the rainy period on the warmer sites over much of the West, and forms a dense stand that dries up and remains on the ground for the remainder of the year if not grazed or burned. Although no experimental tests have been made, volunteer stands of downy chess, both as green plants and as tangled mats of dry vegetation, have effectually checked erosion over extensive areas in the intermountain region and elsewhere, where original plant cover had been destroyed by overgrazing and fire. This has been noted especially at elevations between 2,100 and 7,000 feet in west-central Idaho,

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FIGURE 5.—Erosion being checked by the establishment of grass in the gullies following the washing in of seed from an artificially reseeded area above

on both the basaltic and loose granitic soils on steep slopes. Once established, this annual bromegrass will eventually be largely replaced by more permanent and valuable perennials, provided grazing is properly regulated and fires are kept out. Because its period of palatability is short and since it constitutes a high fire hazard when dry, downy chess should not be employed in artificial range reseeding if other effective species without these drawbacks are available. Wild oat (*Avena fatua*), and rescue grass (*Bromus unioloides*) are

other grasses of value as first aid. Seed of these plants is seldom available on the market but may be harvested at a reasonable cost wherever the species thrive.

The time required for the sown species to become effective in checking erosion depends upon the condition of the ground, the frequency of heavy run-off, and the species used. Where erosion is not of long standing or where extensive and torrential rains do not occur on an average of more than once in two or three years, perennial plants should be effective in two to five years. The more serious the erosion and the greater the frequency of run-off, the longer it will take for the vegetation to occupy the surface. Quick-growing annuals will give the earliest results, usually reaching a maximum ground cover by the second year after sowing.

METHOD OF SOWING

With certain exceptions the methods used in seeding to check erosion are the same as for seeding for forage production. Ordinarily it is advisable to use one and one-half to two times as much seed to check erosion as for improvement of forage crop alone. Harrowing is the best method for planting the seed, although sowing without tilling the soil gives good results where the seed will be covered by soil that blows or rolls into the gullies. Plowing is seldom advisable, since such treatment is not necessary for quick-starting annuals and perennials do not start quickly enough to prevent erosion of the plowed soil on slopes. Trampling the seed in with sheep should not be employed where the land is gullied, since the seed is covered too deeply by the excessive amount of soil that is rolled into the depressions. Areas which accumulate winter snow that melts rapidly in the spring should be sown immediately after the snow goes. If planting is done in the fall the heavy spring run-off may carry away the seed that falls in the gullies. The protection against wind and the accumulation of moisture in the gullies from moderate rains will afford favorable conditions for the growth of the seedlings, even though there is a fairly long dry spell following the melting of the snow.

TERRACING BEFORE SEEDING OR PLANTING

Terraces are used extensively for checking erosion on farm lands. The preparation of these structures, followed by sowing or planting, is an effective means of checking serious erosion on uncultivated lands where immediate results are desired, where the heavy expense is justified, and where sowing or planting without terracing will not suffice. Badly eroding places on municipal watersheds and slopes above home sites or other areas of special use are examples of lands where terracing may be justified. The value of the resource or property to be protected and the seriousness of the damage being done, as measured against the cost of terracing in each case, will determine whether terracing is economically justifiable.

Information on the methods to employ and cost involved in the construction of terraces on farm lands is given in the publications of a number of the State agricultural colleges and in one of the United States Department of Agriculture publications (*26*). Similar meth-

ods, in accordance with circumstances in each case, may be employed on uncultivated lands. Some information on terracing range lands is given in another United States Department of Agriculture bulletin already cited (*30, p. 31*).

Sowing or planting to some suitable species should be done on the terraces to bind the soil and make the improvement more permanent. Sowing is usually most efficacious if done in the fall of the same year the terraces are made. The same directions should in general be followed in selecting the areas and the species to use as for seeding without terraces, except that the work should be concentrated on the more seriously eroded areas. Moreover, growing conditions are usually more favorable on the terraces because of the moisture accumulating from run-off and the protection which the terraces afford against run-off damage before the plants become established. This gives a somewhat greater choice in the selection of species, although it ordinarily pays to select the more hardy, quick-growing varieties.

TRANSPLANTING TO CHECK EROSION

Of the weeds, grasses, and shrubs used in the tests to check erosion by transplanting on the Wasatch Plateau in central Utah, three weedy plants, viz: Sweet sagebrush or sweet sage (*Artemisia incompta*),[7] western yarrow (*Achillea lanulosa*), and Rydberg pentstemon (*Pentstemon rydbergii*) gave the best results, in the order named. They all have vigorous rootstocks, are easily established, and spread to form a dense turf. The expense involved and the slow rate of spread of these species render transplanting of questionable value as compared to seeding of eroded areas. The chief use of these three weeds for transplanting is at intervals in medium to small-sized gullies. Once started in such places their turfs form dams effective in checking the velocity of run-off.

Slender wheatgrass and thickspike wheatgrass, when transplanted, gave much the same results as the three weeds mentioned.

Shrub planting thus far has proved of little value for checking erosion, whether on terraces, along gully sides, or in rows parallel to the contours away from terraces. All of 4,561 individual specimens of stem, sprout, and root cuttings of aspen (*Populus tremuloides aurea*, syn. *P. aurea*) planted along the banks of gullies were failures. Similar results occurred with stem cuttings of bunchberry elder, 3,612 of willow (*Salix* sp.), and 3,073 of gooseberry currant (*Ribes montigenum*). A few transplants of lanceleaf rabbit brush (*Chrysothamnus lanceolatus*) became established, but survival was too low to justify further use of this species. Transplanting of small specimens of bunchberry elder and gooseberry currant gave somewhat better results. A fair proportion of each of these species survived, but their spread, once established, was so slow that after 8 to 10 years it had not been sufficient to influence erosion materially. Under natural conditions, both these species form very dense although not continuous brush thickets of high value for preventing erosion.

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[7] A great many of the species of Artemisia are shrubs, but a number, including *A. incompta*, are herbaceous.

The greatest survival of transplants occurred on terraces where moisture conditions were the most favorable. Only an occasional specimen became established along the banks of gullies, presumably because of the early drying out of the soil, and they checked erosion but little if at all.

The best time for transplanting, as shown by these tests, is in the spring immediately after the snow has melted, when soil moisture is usually sufficient to enable the plants to take root and become fortified against the several weeks of dry weather that usually follow. A delay of as much as three or four days after the snow had disappeared materially increased the number of plants that perished.

FUTURE POSSIBILITIES IN ARTIFICIAL RESEEDING

Up to the present time successful artificial reseeding of range lands has been confined mainly to areas with growing conditions above the average. However, the possibilities of the discovery or development of plants that are adapted to the less favorable conditions and superior to those already successfully introduced in the better areas are by no means exhausted. Thus far the work has been confined principally to cultivated or tame forage plants; yet all of these have not been tried out as fully and under as many conditions as is warranted. Still less work has been done in testing the usefulness of wild or native species, in introducing promising plants from foreign countries, and in developing suitable forms through plant breeding. The field for investigation and work along these lines is still largely unexplored.

The results already obtained, for example, with mountain bromegrass and slender and violet wheatgrasses suggest the possibility that other native forage species might be successfully cultivated. A great many indigenous forage plants, including both grasses and weeds, are fully as valuable for forage in their native state as the three species mentioned. Many of these propagate by rootstocks, and this adds to their value as pasture plants. Since these plants are already adapted to local conditions, the major problems are to determine whether their seed can be produced at a reasonable cost and what response they make to cultivation.

Introduction of plants from foreign countries and the development of superior varieties by selective breeding both offer hope for the future. Nearly all the forage plants now grown in extensive cultivation in the more humid regions of this country have been introduced from the Old World. The successful establishment of such species as alfileria, wild oat, and bur clover on many southwestern ranges indicates the possibility that other forage plants will succeed in the western range region. Much has been done to develop more hardy and more resistant cereals through selection and breeding, and this suggests that similar results might be obtained with range forage plants.

SUMMARY

Investigations and experience indicate that artificial range reseeding will be successful on areas with rainfall, soil, and other growing conditions above the average. Such areas include mountain

meadows, moist parks, alluvial bottoms along streams, and the more favorable slopes, where the average annual precipitation is 17 inches or more, and where restoration of the native vegetation by range management is unpractical. Artificial reseeding can not yet be made to take the place, on any considerable scale, of judicious grazing that will result in natural revegetation of depleted range lands.

In addition to the selection of the more favorable areas, the plants adapted to them, and the probability of restoring the native vegetation, other important considerations include the possibility of restricting grazing of the introduced species until they are well established, and so grazing the reseeded range that the forage crop will be maintained and the expense involved in reseeding will be offset within a reasonable period by increased income.

Whenever artificial reseeding is undertaken with a species hitherto untried in any given locality, the operator, because of the many factors which enter in, should begin the work on a small scale or trial basis.

Certain cultivated species such as common bromegrass, Kentucky and Canada bluegrass, timothy, orchard grass, and redtop have given very satisfactory results in reseeding. Some of the native western grasses, including the big mountain bromegrasses and several of the wheatgrasses, have given equally good results. Their use, however, is limited by the fact that the seed of all except slender wheatgrass may be procured only by collecting it on the range from naturally grown plants. The species thus far found best adapted to the various conditions on western range lands are given in Table 1, page 7.

Methods of treating the land for planting include trampling in the seed with sheep or cattle, harrowing the ground with a farm harrow or a wooden-peg A harrow or brush drag constructed from materials available on the ground, plowing furrows at 3 to 4 foot intervals parallel to the contour of the land, and in some cases complete tillage by plowing and harrowing. Ordinarily, however, conditions will not justify an expenditure of more than $3.50 an acre for the complete operation, including cost of the seed, and only under exceptionally favorable conditions is an outlay of as much as $6 per acre justified. This, on land of average productivity, excludes plowing and usually more than one harrowing.

The best time to seed varies with climatic conditions. The most important consideration is that there should be an ample supply of soil moisture from the time of germination of the seed until seedlings have become well established and deeply enough rooted to withstand drought periods which may occur during the months of favorable growing temperatures.

Where erosion of the soil is occurring as the result of depletion of the plant cover by overgrazing, fire, or other causes, artificial reseeding or planting to restore a plant cover will control the erosion. The methods to employ are much the same as in artificial reseeding to increase forage production, although a higher expense and a greater use of seed per acre are usually justified because of the greater values involved.

Artificial reseeding, as a supplemental measure, sometimes lends itself to temporary conversion of cut-over timberlands to grazing

purposes, pending restocking with tree reproduction as on Douglas fir lands in the Pacific Northwest, provided the seeding and grazing do not interfere with the establishment of tree reproduction. Seeding areas where poisonous plants have been eradicated by grubbing is often justified.

Thus far work in artificial reseeding on range lands has been confined largely to cultivated species and a few native western range plants. There are still many undeveloped possibilities such as further trials with native range plants, the search in foreign countries for plants suited to western range conditions, and the development of more suitable forms by plant breeding and selection. The success with the few native western species tried, the successful introduction into the United States of many foreign species for other purposes, and breeding up of cereals and other crop plants suggest that promising results will be attained as more attention is devoted to range forage plants.

CHECK LIST OF COMMON AND SCIENTIFIC NAMES USED

Common name	Scientific name
Western yarrow	*Achillea lanulosa*
Monkshood	*Aconitum* spp.
Bearded wheatgrass	*Agropyron caninum*
Crested wheatgrass	*Agropyron cristatum*
Thickspike wheatgrass	*Agropyron dasystachyum*
Quack grass	*Agropyron repens*
Streambank wheatgrass	*Agropyron riparium*
Bluestem	*Agropyron smithii*
Blue-bunch wheatgrass	*Agropyron spicatum*
Slender wheatgrass	*Agropyron tenerum*
Violet wheatgrass	*Agropyron violaceum*
Redtop	*Agrostis palustris*
Carpet bent	*Agrostis stolonifera*
Tufted hair grass	*Aira caespitosa*
Meadow foxtail	*Alopecurus pratensis*
Sudan grass	*Andropogon sorghum sudanensis*
Tall oatgrass	*Arrhenatherum elatius*
Sweet sagebrush	*Artemisia incompta*
Australian saltbush	*Atriplex semibaccata*
Wild oat	*Avena fatua*
Beardless pine grass	*Blepharoneuron tricholepis*
Side oats grama	*Bouteloua curtipendula*
Blue grama	*Bouteloua gracilis*
Keeled bromegrass	*Bromus carinatus*
Common bromegrass	*Bromus inermis*
Big mountain bromegrass	*Bromus marginatus*, and close allies.
Polyanthus bromegrass	*Bromus polyanthus*
Porter bromegrass	*Bromus porteri*
Narrowleaf bromegrass	*Bromus subvelutinus*
Downy chess	*Bromus tectorum*
Rescue grass	*Bromus unioloides*
Bermuda grass	*Capriola dactylon*
Lanceleaf rabbit brush	*Chrysothamnus lanceolatus*
Orchard grass	*Dactylis glomerata*
Larkspur	*Delphinium* spp.
Deer grass	*Epicampes rigens*
Alfileria	*Erodium cicutarium*
Arizona fescue	*Festuca arizonica*
Alpine fescue	*Festuca brachyphylla*
Tall fescue	*Festuca elatior* (*N. B.* Meadow fescue is the form of this species known as "*F. pratensis*")

Common name	Scientific name
Idaho fescue	*Festuca idahoensis*
Sheep fescue	*Festuca ovina*
Red fescue	*Festuca rubra*
Greenleaf fescue	*Festuca viridula*
Utah sweetvetch	*Hedysarum utahense*
Curly mesquite grass	*Hilaria belangeri*
Johnson grass	*Holcus halepensis*
Meadow barley	*Hordeum nodosum*
Carrotleaf	*Leptotaenia multifida*
Italian ryegrass	*Lolium multiflorum*
Perennial ryegrass	*Lolium perenne*
Lupine	*Lupinus* spp.
Toothed bur clover	*Medicago hispida*
Alfalfa	*Medicago sativa*
White sweetclover	*Melilotus alba*
Yellow sweetclover	*Melilotus officinalis*
Mountain muhly	*Muhlenbergia montana*
Spike muhly	*Muhlenbergia wrightii*
Velvet grass	*Notholcus lanatus*
Smilo grass	*Oryzopsis miliacea*
Sweet-anise or western aniseroot	*Osmorhiza occidentalis*
Browns peony	*Paeonia brownii*
Dallis grass	*Paspalum dilatatum*
Rydberg pentstemon	*Pentstemon rydbergii*
Reed canary grass	*Phalaris arundinacea*
Timothy	*Phleum pratense*
Bulbous bluegrass	*Poa bulbosa*
Canada bluegrass	*Poa compressa*
Mutton grass or Fendler bluegrass	*Poa fendleriana*
Nevada bluegrass	*Poa nevadensis*
Kentucky bluegrass	*Poa pratensis*
Rough bluegrass	*Poa trivialis*
Wheeler bluegrass	*Poa wheeleri*
Aspen	*Populus tremuloides aurea* (syn. *P. aurea*)
Squaw currant or rock currant	*Ribes inebrians*
Gooseberry currant	*Ribes montigenum*
Willow	*Salix* spp.
Bunchberry elder	*Sambucus microbotrys*
Squirreltail grass	*Sitanion hystrix*
Black dropseed	*Sporobolus interruptus*
Letterman needle grass	*Stipa lettermani*
Western needle grass	*Stipa occidentalis*
Green needle grass	*Stipa viridula*
Alsike clover	*Trifolium hybridum*
Red clover	*Trifolium pratense*
White clover	*Trifolium repens*
False-hellebore	*Veratrum* spp.

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